Physical activity, sedentary behaviour, and mood symptoms, in people living with bipolar disorder

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Declarations

1. I declare that no material contained in this thesis has been used for any other submission for an academic award.

2. I declare that the contribution claimed in this thesis is original, and a result of my own work.

Signed:  ***Date:*** 18th May 2021

Gemma Kay McCullough

Acknowledgements

University of Worcester

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Participants

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PhD students

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Abstract

Background

Previous research has established links between physical activity (PA), sedentary behaviour (SB), and mental wellbeing. Little is known about PA and SB engagement in relation to (hypo)manic and depressive symptoms in people living with bipolar disorder (BD).

Aims

The main aims of this PhD were to explore *perceived*, *device-measured*, and *subjectively* measured relationships between PA, SB, and mood in people living with BD. A further aim was to explore the validity of the MSQ as a self-report SB tool in this population.

Method

Participants with DSM-IV BD were recruited from the Bipolar Disorder Research Network.

Study one consisted of semi-structured qualitative interviews on PA, SB and mood analysed using a thematic analysis (N=15).

In study two, PA and SB were measured using an ActivPAL3 over 7-days (N=51). Daily (MoodZoom) and weekly (QIDS & ASRM) mood measures were completed, alongside the MSQ to compare to the ActivPAL3.

For study three, self-report 7-day recall questionnaires subjectively measured PA (IPAQ), SB (MSQ), and mood symptoms (BDI-21 & ASRM) (N=1031).

Findings and Discussion

Interviews revealed that participants were striving to find a balance of not being too sedentary or too physically active to keep mood within manageable limits. Device-measured daily moderate/vigorous PA (MVPA) was positively associated with daily ratings of *'elation' ($r=0.21, p<0.01$)* and *'energy' ($r=0.21, p<0.01$)* in females only, and negatively associated with *'sadness' ($r=-0.24, p<0.001$). S*ubjectively measured weekly MVPA was also negatively associated with depression symptom severity *($r=-0.13, p<0.001$)*. Device-measured weekly SB was positively associated with (hypo)mania symptom severity in those who reported using anti-depressants *($r=0.60, p<0.05$)*, and using the MSQ time spent sitting for *'leisure'* was positively associated with (hypo)mania symptom severity *($r=0.08, p<0.05$)*, but negatively with depression symptom severity *($r=-0.12, p<0.01$)*. On average the MSQ underestimated SB by 47mins, however showed acceptable validity *($r=0.283-0.344$)* and agreement with the device-based measure, and so should be used with caution when exploring SB in BD in future studies.

People living with BD experience complex PA, SB, and mood relationships which are challenging to balance. The results suggest MVPA may be helpful for overcoming depressive symptoms however may complicate the self-management of (hypo)mania and disrupt the 'balance.' Health professionals could consider personalised recommendations for PA/SB engagement for this population which account for current mood state rather than the standardised PA recommendation of 75-150mins MVPA per week. Future research could consider longitudinal prospective designs to examine temporal relationships between PA, SB and mood in people living with BD.

Abbreviations of measures:

MSQ – Marshall Sitting Questionnaire

QIDS – Quick Inventory of Depressive Symptoms

ASRM – Altman Self-Rating Mania Scale

IPAQ - International Physical Activity Questionnaire

BDI-21 – Beck Depression Inventory

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1 Chapter One: Introduction

1.1 Rationale

Regular physical activity (PA) has well known physical health benefits within the general population (McKinney et al., 2016; Reiner, Niermann, Jekauc, & Woll, 2013; Warburton & Bredin, 2016; Warburton, Nicol, & Bredin, 2006). Research has also evidenced a link between regular PA and improved mental health outcomes, particularly in those who experience depression (Bailey, Hetrick, Rosenbaum, Purcell, & Parker, 2018; Conti & Ramos, 2018; Kandola, Ashdown-Franks, Hendrikse, Sabiston, & Stubbs, 2019; López-Torres Hidalgo et al., 2019; Murri et al., 2019; Rebar & Taylor, 2017; Schuch & Stubbs, 2019; Stanton & Happell, 2014). More recently, research has also established a link between spending too much time in sedentary behaviour (SB) (sitting or lying down) and an increase in depressive symptoms (Adamson, Yang, & Motl, 2016; Stubbs et al., 2018b; Teychenne, Ball, & Salmon, 2010; Zhai, Zhang, & Zhang, 2015).

However, it is unclear how the above relationships between PA, SB and depression present in people living with bipolar disorder (BD), who not only experience episodes of depression, but contrasting episodes of high mood known as (hypo)mania (American Psychiatric Association, (APA, 2013)). Bipolar disorder is a relatively common episodic mood disorder (Merikangas et al., 2011), and people living with BD are at an increased risk of developing a number of physical health conditions; particularly type-2 diabetes (McGinty, Baller, Azrin, Juliano-Bult, & Daumit, 2016), cardiovascular disease (Pérez-Piñar et al., 2016) and obesity (Elmslie, Mann, Silverstone, Williams, & Romans, 2001). The risk of developing such physical health conditions can be reduced by increasing time spent in PA, and reducing the amount

of time spent in SB (Kerling et al., 2015; Masa-Font et al., 2015; Pérez-Piñar et al., 2016; Proper, Singh, Van Mechelen, & Chinapaw, 2011; Reiner et al., 2013) and so a greater understanding of the PA and SB engagement of this population, and any relationship with mood symptoms, is well warranted. The Chief Medical Officer's Report (CMO, 2015, 2019) recommends that adults engage in at least 75mins of vigorous or 150mins of moderate PA weekly and make efforts to break up SB such as sitting time daily. However, some research has suggested people living with BD regularly do not meet these guidelines, and are significantly more sedentary and less active than the general population (Elmslie et al., 2001; Janney et al., 2014; Jewell et al., 2015; Shah et al., 2007), which further prompts the need to explore PA and SB in relation to mood symptoms in this population given the physical and mental health implications of not engaging in enough PA, and too much SB.

Although there has been some interest in the relationship between PA and mood for the purposes of mood stability, and the self-management of mood symptoms in BD (Ng, Dodd, & Berk, 2007; Proudfoot et al., 2012; Sylvia et al., 2013b; Wright, Everson-Hock, & Taylor, 2009; Wright, Armstrong, Taylor, & Dean, 2012), there are some considerable limitations to this research including the use of unvalidated and/or unsuitable measures of PA and SB, mixed population samples, small sample sizes of people with BD, a lack of information on (hypo)manic mood symptoms, and very few explorations into day-to-day PA other than specific exercise. Furthermore, very little is known about the relationship between SB and mood symptoms in particular; firstly because SB has been measured infrequently and using unsuitable measures in previous research, and secondly because the relationship between SB and the (hypo)mania symptoms experienced by people living with BD has remained unexplored.

Previous research which has explored PA and/or SB in people living with BD has not yet assessed PA or SB well enough to draw adequate conclusions regarding the levels of PA and SB engagement and any association with mental and physical health in this population. Self-report measures have formed the bulk of the data suggesting people living with BD are less active and more sedentary than the general population. However, there is no validated SB self-report tool for people with BD, and so these findings are brought into question. It is important to understand the validity of self-report tools in this population, as people living with BD can experience severe impairment and changes in mood, cognition, and behaviour uncharacteristic of the general population in which these tools were originally designed for and validated in, and therefore may not accurately capture the SB levels of people living with BD. Therefore, exploring PA and SB further using the most accurate measurements is required to have confidence in our understanding of the PA and SB levels of people with BD, and the relevance of any relationships between PA, SB and the complex mood symptoms which are characteristic of this population. This is required to make supported, evidence-based recommendations for the engagement of PA and SB in people living with BD to prevent the onset or worsening of symptoms of physical illnesses, whilst managing any perceived or measurable association with BD mood symptoms. In sum, understanding PA, SB and mood more effectively could result in the improved treatment and management of BD.

This PhD thesis is therefore an exploration of PA, SB and mood symptoms in people living with BD.

1.2 Thesis structure

Figure 1.1 below outlines the structure of this PhD thesis and the progression of three studies through seven chapters, and illustrates the integrated approach taken using mixed methods.

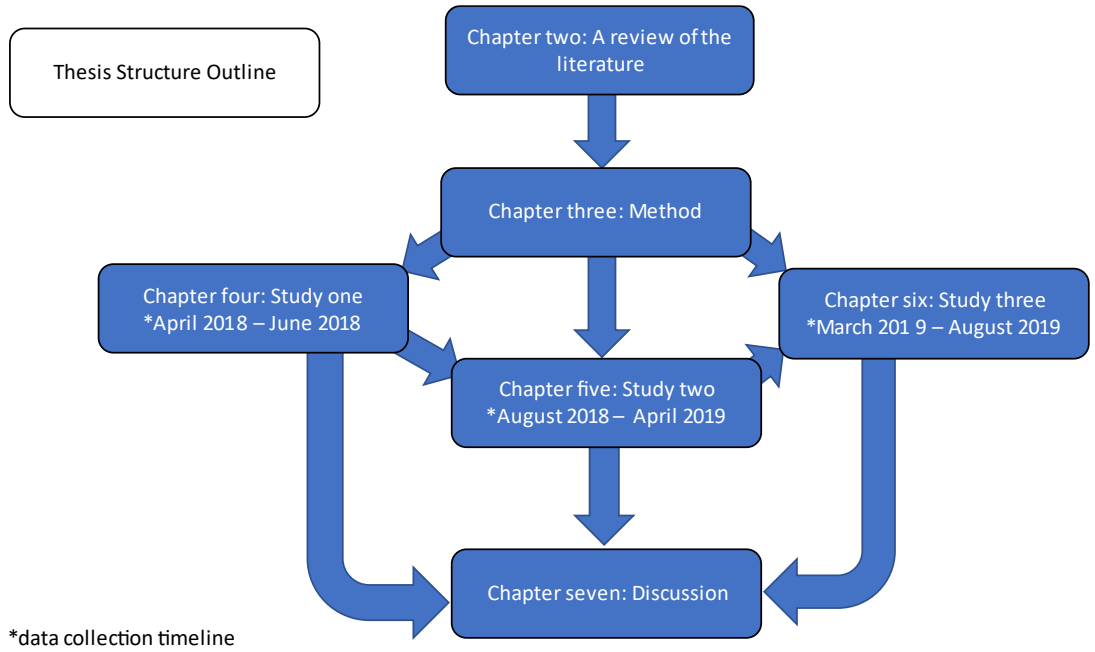


Figure 1.1 Structural outline of PhD thesis

Chapter two: is a review of the literature concerning PA and SB and their means of measurement and highlights the limitations of previous research which has explored PA and/or SB in people with BD, concluding with the research question and specific aims of this PhD thesis.

Chapter three: presents the method of this PhD thesis, including the philosophical underpinnings, a discussion of mixed methods, and justifications for the specific approach and methods used throughout this PhD, followed by details of participant recruitment and ethical implications.

Chapter four: presents the method, findings, and discussion of the first study, a qualitative exploration into 'the perceived relationships between PA, SB and mood in people living with BD.'

Chapter five: presents the method and results of the second study, a quantitative exploration into 'device-measured relationships between PA, SB and self-reported mood symptoms in people living with BD.' The chapter concludes with a discussion of the results, which are also considered in relation to the findings of study one.

Chapter six: presents the method and results of the third study, a quantitative exploration into 'subjectively measured relationships between PA, SB and self-reported mood symptoms in people living with BD.' The chapter concludes with a discussion of the results, which are also considered in relation to the study one and study two findings.

Chapter seven: provides a full synthesis of the results from all three studies (chapters four-six), followed by implications for people living with BD and for future research, the original contributions to knowledge and strengths and limitations of this PhD, and ends with the conclusions of this PhD thesis.

2 Chapter Two: A review of the literature

2.1 Introduction

This chapter is a review of the literature pertaining to definitions and measurement of physical activity (PA) and sedentary behaviour (SB) and highlights the importance of understanding PA and SB in relation to mental wellbeing, and why particularly in bipolar disorder (BD). This is followed with a more critical review of the literature which has explored PA and/or SB in people living with BD, followed by the conclusions of this review chapter and the research question and specific aims which then guided this PhD thesis.

2.2 Physical activity

Physical activity (PA) is defined as any movement of the body, specifically using the skeletal muscles, that requires energy expenditure to be completed (Caspersen, Powell, & Christenson, 1985; World Health Organization (WHO) 2017). PA behaviours vary in intensity and the energy required to carry them out (energy expenditure). Energy expenditure is measured in METs (metabolic equivalents of task), which describes an individual's metabolic rate compared with their normal, resting rate of metabolism when sitting still (1-1.5METs) (WHO, 2017) and describes the energy cost of engaging in different PA intensities. Light intensity PA includes behaviours using less than 3 METs, but more than 1.5 METS, such as standing, and walking at a normal pace. Moderate intensity PA requires more physical effort than light PA and a noticeable increase in heart rate, and includes activities requiring approximately 3-6 METs, such as dancing, brisk walking, gardening, and

carrying/moving moderate loads (<20kg). Vigorous intensity PA requires substantial physical effort and a significant increase in heart rate, and describes activities requiring more than 6 METs, such as running, hill climbing, carrying/moving heavy loads (>20kg), and some competitive sports such as football (WHO, 2017). The Chief Medical Officer's Report (CMO, 2015, 2019) recommends that adults aged 18-64 years old engage in at least 150mins of moderate PA, 75mins of vigorous PA, or some combination of both (MVPA) per week and engage in strength-building activities such as resistance training twice a week as part of an active, healthy lifestyle. The 75-150 mins of recommended weekly MVPA should be achieved in bouts of at least 10mins or more to be considered as beneficial to physical health (WHO, 2017). The term PA therefore covers a wide range of daily behaviours across work, travel, household and leisure domains, including activities such as walking, cycling, shopping, cleaning and gardening.

2.2.1 Physical exercise

Physical exercise falls under the umbrella term of PA as a subcategory and is often a term used synonymously with PA. However, physical exercise is distinct from PA in that PA includes all active behaviours, but not all active behaviours are considered exercise (Winter & Fowler, 2009). Exercise is a consciously planned, structured and repeated activity carried out to keep fit and healthy with an aim to improve or maintain physical fitness (Caspersen et al., 1985).

2.2.2 Physical fitness

Physical fitness refers to a range of measurable skills-related (agility, balance, speed, power, reaction time and coordination) and health-related (muscular strength and endurance, flexibility, and cardio-respiratory health) components which relate to

PA (Caspersen et al., 1985). Physical fitness is not another subcategory of PA; however, it is something that requires PA to be maintained and improved. Physical fitness is therefore complex and difficult to measure, as individuals can vary between skills-related and health-related physical fitness. However, overall the term is used to describe the level at which someone can carry out daily, expected PA as well as any additional unforeseen PA requirements without fatigue or risking injury, whilst maintaining an element of enjoyment (Caspersen et al., 1985).

2.2.3 Physical activity & physical health

Regular PA has well known physical health benefits, these include: achieving and maintaining a healthy weight; improving and maintaining physical fitness; and reducing the risk of developing various physical health conditions including obesity, type 2 diabetes, hypertension, cardiovascular disease and some cancers (CMO, 2015; 2019; Ekelund et al., 2016; Reiner et al., 2013; Warburton & Bredin, 2016; Warburton, Nicol, & Bredin, 2006). Further, the WHO (2017) identified physical inactivity as the fourth leading risk factor for global mortality, contributing to the prevalence of non-communicable diseases such as obesity, type 2 diabetes and cardiovascular disease.

Recent systematic reviews exploring PA levels have highlighted that a large proportion of the general population do not meet the PA guidelines of 75mins-150mins of MVPA per week (Adamson et al., 2016; Haider, Grabovac, & Dorner, 2018; Helgadóttir, Forsell, & Ekblom, 2015; Marques et al., 2016; Marques, Sarmento, Martins, & Saboga Nunes, 2015). The Active Lives Survey (Department for Digital, Culture, Media and Sport, 2020) reported that 63% of people over the age of 16 in England self-reported engaging with at least 150mins of moderate PA

weekly. Someone can appear very physically active and not necessarily meet the CMO guidelines' recommendations. If the activity is not deemed to be moderate to vigorous, e.g., if someone's employment requires them to be standing or walking throughout the day, but at a slow pace, they are not considered to be meeting the CMO guidelines despite being considerably active throughout the day. It is also possible for someone to be meeting the CMO guidelines by doing 75mins of vigorous activity once a week, whilst being almost entirely sedentary the rest of the week. Recent literature has raised the query of whether there should be specific guidelines or recommendations for people with mental illness engaging in PA (Firth et al., 2019; Vancampfort, Stubbs, Ward, Teasdale, & Rosenbaum, 2015; Warburton & Bredin, 2016) to encourage people living with mental illness to take small steps towards increasing their PA, without being put off by a single recommendation of 75-150mins of MVPA to improve the populations' physical and mental health.

2.2.4 Physical activity & mental health

As well as the many physical health benefits of engaging in PA such as maintaining fitness, staying healthy, and reducing the likelihood of developing a serious health condition, there are also psychological benefits attainable from engaging in regular forms of PA, including improved mental health (Eime, Young, Harvey, Charity, & Payne, 2013; Mason & Holt, 2012; Strohle et al., 2007). Evidence has shown that increased exercise is associated with improved overall mood and reduced levels of depression in people that experience depression (Schuh et al. 2016a, Schuh et al. 2016b), and a systematic review by Vancampfort et al., (2018a) into PA and suicidal ideation found that higher PA levels were associated with lower suicidal ideation across adolescents, adults and older adult populations. The exact cause for the improved mental health outcomes that come with a form of regular PA engagement,

and particularly exercise, is uncertain, however may be due to several factors. This could be a combined result of any social aspect of PA increasing enjoyment and social companionship (Eime et al., 2013); engaging in PA outside in green, nature spaces (Yeh et al., 2016); feeling fit and healthy following PA (Firth et al., 2016a); achievement motivation (Parker et al., 2016; Rhodes, Quinlan, & Mistry, 2016); and biological effects of PA such as the effect of increased hippocampal volume (Erickson et al., 2015; Firth et al., 2018b; Thomas et al., 2016); and improved cognition and brain functioning (Erickson et al., 2015).

2.3 Sedentary behaviour

Sedentary behaviour (SB) is defined as sitting, lying or reclining during waking hours with an energy expenditure of -1.5 METs by the Sedentary Behaviour Research Network (SBRN, 2017) (Tremblay et al., 2017). SB describes behaviours such as sitting watching television, working at a desk, sitting whilst travelling, i.e., sitting on a train, bus, or in a car, and lying down (whilst awake). Sleeping is not SB, as the energy expenditure associated with sleeping is -1 METs and is the body's means of resting and repairing (SBRN, Tremblay et al., 2017). CMO guidelines recommend actively breaking up sitting time daily as part of a healthy lifestyle. SB is a term often used synonymously with physical *inactivity* however it is a different construct: SB referring to sitting or lying behaviours, and physical inactivity referring to not meeting the CMO PA guidelines. It is therefore possible to be 'physically active' (by meeting the CMO PA guidelines) but also be highly sedentary, which has implications for physical and mental health.

2.3.1 Sedentary behaviour & physical health

Alongside physical inactivity, research has established that too much time in SB is associated with poor physical health in adults in the general population (CMO report, 2015, 2019; Proper, et al., 2011). A systematic review identified SB is associated with all-cause cardiovascular disease and type 2 diabetes (Proper et al., 2011). More time spent in SB, particularly watching television, has been associated with obesity (Heinonen et al., 2013; Shields & Tremblay, 2008) which is also a potential risk factor for cardiovascular problems (Heinonen et al., 2013). Furthermore, Shields and Tremblay (2008) reported that a quarter of people who self-reported more than 21hrs sitting watching television per week were classed as obese, and were therefore at greater risk of further physical health complaints as a result. The association of obesity and engaging in SB by watching television may be explained by the theory that people who watch more television also engage in less mindful eating habits, possibly due to being less engaged with what they are watching due to over-exposure to similar content (Mathur & Stevenson, 2015). It is clearly important to understand the impact of lifestyle factors (such as television viewing) wherever possible when exploring SB to effectively target and modify the SB behaviours engaged with the most to see improved physical health outcomes and reduced health risks.

2.3.2 Sedentary behaviour & mental health

More recently, it has been evidenced that too much time engaged in SB can also be harmful for mental health (Adamson et al., 2016; Faulkner & Biddle, 2013; Giurgiu et al., 2019; Hallgren et al., 2019; Zhai et al., 2015). High SB levels have been identified as a risk factor for depressive symptoms (Adamson et al., 2016; Stubbs et

al., 2018b; Teychenne et al., 2010; Zhai et al., 2015) and anxiety symptoms (Stubbs, et al., 2018b; Teychenne, Costigan, & Parker, 2015). Research has further established an association between SB and mental health by evidencing that people who experience depression are more sedentary than the general population (Janney et al., 2014; Melo et al., 2016; Vancampfort et al. 2016d). A recent systematic review has also identified a positive relationship between higher levels of SB and higher severity of depressive symptoms, longer illness duration, and higher doses of anti-psychotic medication in those living with a serious mental illness (Bort-Roig et al., 2020).

Furthermore, Giurgiu et al., (2019) identified that the more sedentary people were, the more they reported feeling less 'well' and less energised throughout the day, and it was recently identified that current mood may predict and regulate SB engagement (Giurgiu et al., 2020), indicating a possible bidirectional relationship between SB and mood. Giurgiu et al., (2019) also concluded that PA and SB may show different effects on mood and highlight a need to assess the relationship between PA and mood and SB and mood independently, as well as the relationship between PA and SB.

2.4 Physical activity & sedentary behaviour

The previous section identified that low levels of PA, and high levels of SB, are both associated with various physical health conditions such as cardiovascular disease, type II diabetes, and obesity, and are both also potential risk factors for the onset of these conditions. Obesity is a risk factor for cardiovascular disease and type 2 diabetes (Centres for Clinical Diseases, 2020; National Heart, Lung, and Blood Institute, 2013; Piché, Tchernof, & Després, 2020), as well as some cancers

(Bhaskaran et al., 2014), and so there are clear health risks from engaging in low levels of PA, and high levels of SB, and therefore a strong rationale for exploring PA and SB simultaneously to understand the relationship between the two constructs as well as their individual impact. Mansoubi, Pearson, Biddle, and Clemes (2014) investigated the relationship between PA and SB in the general population through a systematic review including 26 studies which had measured both PA and SB and reported on the association between them. The review reported on associations of different SB domains (for example watching television, other screen time and occupational sitting) with PA intensities (light PA and MVPA) and other PA categories (for example work related PA, travel related PA, and exercise). The strongest associations identified in the systematic review were negative associations between time spent in exercise and sitting watching television, and total time spent in SB with MVPA and light PA. The studies included in the review varied in method (self-report questionnaires or data from wearable activity monitors) which may explain why the strength of the identified associations between PA and SB varied from weak to moderate between studies measuring the same PA categories and SB domains, and further highlights a need to consider the collective role of PA and SB in relation to population health concerns rather than solely exploring the individual role of PA or SB.

Given the low level of PA engagement and high level of SB engagement within the general population, there has been growing interest in identifying the levels of PA (particularly MVPA; Paolucci, Loukov, Bowdish, & Heisz, 2018) and SB engagement across various groups to explore whether their PA and SB engagement differs from the general population, and to identify any populations that are at risk from illness due to not engaging in enough PA, or too much SB. These include: children and

adolescents (Bouchard, Claude, Tremblay, Leblanc , Lortie, Savard, 1983; Cust, 2007; Erickson et al., 2015; He, Paksarian, & Merikangas, 2018; Jewell et al., 2015); older adults (over 65 years) (Dugan, Gabriel, Lange-Maia, & Karvonen-Gutierrez, 2018; Erickson et al., 2015; López-Torres Hidalgo et al., 2019); and particularly vulnerable and/or at risk populations (Pedersen & Saltin, 2015) such as the physically disabled or injured (Rimmer, Riley, Wang, Rauworth, & Jurkowski, 2004; Shirazipour, Evans, Leo, Lithopoulos, Martin Ginis & Latimer-Cheung, 2020) those living with (or at risk of developing) a chronic physical illness (Gaughran et al., 2019; Heinonen et al., 2013; McKinney et al., 2016; Piché et al., 2020; Shields & Tremblay, 2008; Yerrakalva, Mullis, & Mant, 2015), and those with a serious mental illness (SMI) (Correll et al., 2017; Daumit et al., 2020; Osborn et al., 2018; Vancampfort et al., 2017c; Vancampfort et al., 2015e; Vancampfort et al., 2015f). People living with an SMI have been highlighted as having a greater risk of developing and dying from cardiovascular disease in their lifetime (McGinty et al., 2016). Correll et al., (2017) report this risk as being 78% higher (with an 85% higher risk of dying from the condition) than those without an SMI. The WHO (2016) published a report on mortality in people living with SMIs, and reported the leading cause of death as being preventable physical illnesses such as cardiovascular disease (with death occurring 10-20 years earlier than those without an SMI); and Colton and Manderscheid (2006) and Daumit et al., (2013) estimate the risk of dying from the condition as being approximately two thirds higher in people living with an SMI. It is therefore necessary to understand PA and SB in relation to SMIs, as PA and SB are modifiable risk factors of physical illnesses which have a high prevalence in people living with an SMI. As people living with an SMI have been identified as being at a greater risk of developing and dying from chronic physical health conditions than the general

population, it is important to understand the implications of PA and SB engagement on mental health to encourage sustainable and effective lifestyle changes to increase PA and reduce time spent in SB.

There has been a plethora of recent research into PA and SB levels in people living with SMIs which include schizophrenia (Brokmeier et al., 2019; Bueno-Antequera, Oviedo-Caro, & Munguía-Izquierdo, 2018; Deenik et al., 2017; Soundy, Stubbs, Probst, Hemmings, & Vancampfort, 2014b; Vancampfort et al., 2017b), major depressive disorder (Morgan, Olagunju, Corrigan, & Baune, 2018; Olson, Brush, Ehmann, & Alderman, 2017; Schuch et al., 2016a; 2016b; 2016c; Stubbs et al., 2018b) and bipolar disorder (Folke la Karottki et al., 2020; Janney et al., 2014; Kilbourne et al., 2007; Melo, Daher, Albuquerque, & de Bruin, 2016; Melo et al., 2019; Ng et al., 2007; Vancampfort et al., 2015h). This research has primarily been focused on establishing the PA and SB levels of these populations, often as one SMI group rather than by diagnosis, largely concluding that those living with an SMI are less active and more sedentary than the general population. However, given the positive associations between regular PA and improved mental health, and negative associations between high levels of SB and poor mental health in the general population, there is a growing interest in how regular PA in particular may support the self-management of symptoms that are present in those living with bipolar disorder, as not only do this population experience depressive symptoms (as with major depressive disorder) and potentially psychosis (as with schizophrenia), but episodic symptoms of high mood unique to the illness (Harrison et al., 2016; Ng, Dodd, & Berk, 2007; Proudfoot et al., 2012; Sylvia et al., 2013a; Wright, Everson-Hock, & Taylor, 2009; Wright, Armstrong, Taylor, & Dean, 2012).

2.5 Bipolar disorder

2.5.1 The presentation of bipolar disorder

Bipolar disorder (BD) is a relatively common mental health condition, with a lifetime prevalence of approximately 1% worldwide (Merikangas et al., 2011). Specifically, BD is an episodic mood disorder characterised by recurring episodes of high mood, and usually, contrasting episodes of depression (American Psychiatric Association, (APA), 2013). A high mood episode is characterised by a noticeably elevated mood state, and changes such as an inflated self-esteem, a decreased need for sleep, and an increase in energy and goal-orientated activity. A depressive episode is characterised by a severely inhibited mood state, and changes such as feelings of worthlessness, a diminished interest in almost all activities, fatigue, and often, suicidal ideation (APA, 2013). People living with BD can also experience 'mixed state' episodes where there are high and low mood symptoms present. Subtypes of BD describe the severity of mood episodes experienced by an individual (see figure 2.1 below): BD type I (BDI) describes individuals who experience severely elevated mood episodes called mania, and type II (BDII) describes individuals who experience slightly less severe high mood episodes called hypomania (APA, 2013). Someone with BDI can also experience episodes of hypomania. BD is most often diagnosed in the UK using the International Statistical Classification of Diseases (current edition at 2020: ICD-10), however this does not distinguish between BDI and BDII subtypes (Phillips & Kupfer, 2013), or the Diagnostic Statistical Manual of Mental Disorders (current edition at 2021: DSM-5). The DSM-5 requires a mania episode lasting at least one week for BDI; or a hypomania episode lasting at least four days for BDII. However, people living with BD often experience depressive episodes years before having a (hypo)manic episode which can be problematic as the prescription of anti-

depressants to treat depression can lead to a (hypo)manic episode in those with BD (Phillips & Kupfer, 2013). Depression needs to last for at least two weeks to be considered a depressive ‘episode’, regardless of BD subtype (APA, 2013).

The requirement of a (hypo)mania episode means many people with BD are either misdiagnosed or initially diagnosed with unipolar or major depression, before later having their diagnosis changed to a subtype of BD (Daveney, Panagioti, Waheed, & Esmail, 2019). This is particularly important for those with BDII who may experience hypomania most of their illness, before having a manic episode later in life which would change their diagnosis. Someone with a diagnosis of BDII can therefore have this changed to BDI, however someone with BDI would not be re-diagnosed to BDII, even if they have only ever had one manic episode (APA, 2013). Due to the updating of the DSM criteria (DSM-5: APA, 2013), some patients may meet the diagnosis requirements in one version, but not in a later version (DSM-IV: APA, 1994; DSM-IV-TR: APA, 2000). However, literature suggests the most recent changes from DSM-IV to DSM-5 has had little impact on the lifetime diagnosis of BD across the UK population (Gordon-Smith, Jones, Forty, Craddock, & Jones, 2017). Other, less common, subtypes of BD include cyclothymic disorder, schizoaffective disorder and ‘unspecified bipolar and related disorders’ (APA, 2013).

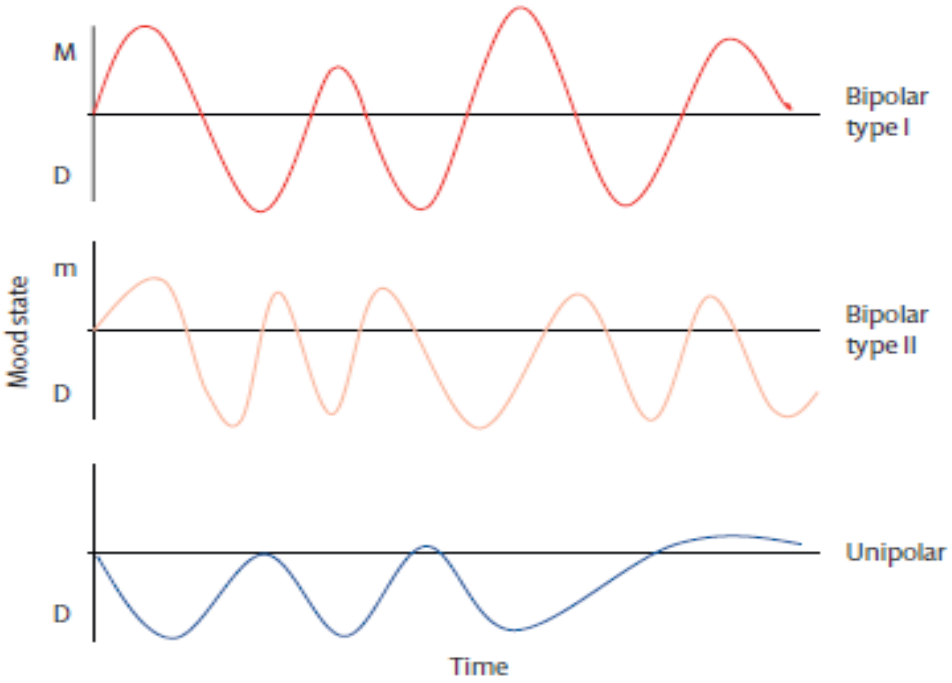


Figure 2.1 Phillips and Kupfer (2013) mood changes over time in BDI, BDII and unipolar depression (M=mania, m=hypomania, D=depression). Copyright permission obtained from Elsevier February 2021

Figure 2.1 shows that those with BDII typically experience more frequent episodes of depression over the course of their illness than those with BDI, however these are usually shorter in duration than those with BDI. Those with BDII also experience more frequent episodes of hypomania than the mania episodes experienced by those with BDI (Phillips & Kupfer, 2013).

BD has been shown to affect men and women equally as previous research has revealed little evidence of gender differences in the presentation of BD, although pregnancy and childbirth are additional risk factors for mood episodes in women (Diflorio & Jones, 2010). There is also little evidence to suggest that nationality, ethnic origin or socioeconomic status significantly impact on the likelihood someone will develop BD (Grande, Berk, Birmaher, & Vieta, 2016). The National Institute of Mental Health (2020) and APA (2019) report that the typical onset of BD symptoms

is late adolescence or early adulthood, although some people do show symptoms in early childhood, and some will not show diagnosable symptoms until later in life (APA, 2013; 2019). Age at diagnosis also varies greatly due to the difficulty in distinguishing BD from other mental health conditions that show close symptom comorbidity, such as schizophrenia, unipolar depression, and anxiety disorders (APA, 2013) and in childhood and adolescents, attention deficit hyperactivity disorder (ADHD) (APA, 2013).

As well as high comorbidity with other mental health disorders, people with BD are at an increased risk of developing a number of physical health conditions, particularly type-2 diabetes (McGinty et al., 2016) cardiovascular disease (Pérez-Piñar et al., 2016) and obesity (Elmslie et al., 2001). It was also identified above that the risk of developing such physical health conditions can be reduced by increasing time spent being physically active, and reducing the amount of time in SB (Kerling et al., 2015; Masa-Font et al., 2015; Pérez-Piñar et al., 2016; Proper et al., 2011; Reiner et al., 2013). However, research has shown people living with BD regularly do not meet the CMO PA guidelines, and are less physically active than the general population (Janney et al., 2014; Jewell et al., 2015; Kilbourne et al., 2007; Melo et al., 2016). Given it was identified in the previous section that a large proportion of the general population do not engage with enough PA, this highlights a particular need to explore and understand PA and SB engagement in people with BD as they have been described as being less physically active, more sedentary, and at greater risk of developing and dying from physical illness as a result. They are also a population that may have the most to benefit from engagement in more PA and less SB due to mental health benefits as well as the physical health benefits.

2.5.2 The aetiology, management, & treatment of bipolar disorder

Research to date has indicated that BD is a multifactorial condition (APA, 2013) influenced by genetics (Hamshere et al., 2011; Johansson, Kuja-Halkola, Cannon, Hultman, & Hedman, 2019) and environmental factors (Fletcher, Parker, & Manicavasagar, 2012; Grande et al., 2016; Proudfoot et al., 2014, 2012), including personal experiences, for example trauma (Grande, et al. 2016). However, the precise causes of BD remain unclear, and so further research into the expression of symptoms and any relationship to PA and SB is required to understand PA and SB better in this population, to optimise the treatment and management of BD and to support research into the aetiology and presentation of BD. When exploring the expression of symptoms and constructs such as PA or SB in people with BD, research using heterogeneous samples offer further opportunity to explore any differences between factors such as gender in the engagement of PA or SB in this population. Even though previous research suggests that demographic factors do not necessarily contribute to the onset of BD, they may still be relevant for establishing the best support for regulating PA and SB engagement to see improved physical and mental health outcomes, and so require further exploration.

As BD also has high comorbidity with other mental disorders (APA, 2013), diagnosing and treating BD, as well as understanding the symptomology of BD specifically is challenging, and this has an impact on the individual living with BD, as people living with BD demonstrate lower levels of employment that the general population (Alonso et al., 2011); the National Health Service (NHS); and service providers involved with treatment (Daveney et al., 2019). BD has been estimated to cost the UK NHS in excess of 342 million pounds annually due to costs associated with treatment, periods of hospitalisation and co-morbid conditions (Young et al.

2011), demonstrating the severity of this lifetime condition, and the need for cost-effective and successful treatment options. As well as the previously identified comorbidity between various physical health conditions reducing life expectancy in BD, people diagnosed with BD are also more likely to die by suicide than the general population, with up to 1 in 4 people with BD attempting suicide at some point during their illness (Merikangas et al., 2012). This furthers the need for a greater understanding of PA engagement in this population, as regular PA has been associated with lower levels of suicidal ideation (Vancampfort et al., 2018a).

There is no established 'cure' for BD, however the condition is manageable with appropriate, individualised treatment (APA, 2013). The treatment for BD is complex and varied, usually requiring a combination of medication such as mood stabilizers, and often, anti-psychotics (Fountoulakis & Vieta, 2008; Kishi et al., 2020). Research has evidenced that identifying the correct medication and dosage for an individual with BD can be challenging and can take considerable time to get 'right' for an individual, with changes being made to manage episodes and relapses (Fountoulakis & Vieta, 2008; Kishi et al., 2020; Nivoli et al., 2011) and to manage any side effects. This highlights the complexity of BD and issues that may arise when managing BD with medication alone. Research has also evidenced that some psychiatric medications such as antipsychotics can also have a negative effect on energy levels which is important when considering engagement with PA and SB as PA engagement requires energy, and being physically active then expends energy (Correll, Detraux, De Lepeleire, & De Hert, 2015; Gaughran et al., 2019; Perez-Cruzado, Cuesta-Vargas, Vera-Garcia, & Mayoral-Cleries, 2018; Suetani et al., 2016). In addition, people with BD may also have to consider the impact of any BD medication in relation to other medications taken for co-morbid physical or mental

health conditions which may impact on PA and SB engagement, or the ability to physically engage in PA. The impact of medication is therefore an important consideration, of which a greater understanding may help to explain why people with BD have been identified as less active and more sedentary than the general population.

Psychological interventions are also commonly used to treat and manage BD (Brenner & Shyn, 2014; Chu et al., 2018; Gartlehner et al., 2016; Oud et al., 2016; Stratford, Cooper, Di Simplicio, Blackwell, & Holmes, 2015) including mindfulness and cognitive behavioural therapy (Chu et al., 2017; Lovas & Schuman-Olivier, 2018; Oud et al., 2016). These interventions challenge unhelpful thought patterns and aid relaxation to develop a heathier mind-set and to provide the tools to live with and effectively manage BD mood symptoms. This is often followed with an action or care plan, which identifies potential triggers and early warning signs for a mood episode, highlighting when the individual should seek help from mental-health professionals such as a psychiatrist or community psychiatric nurse, and what they can do themselves to avoid a full-blown mood episode. However, it remains unclear whether PA or SB are considered to be triggers/early warning signs of mood changes in BD (Proudfoot et al., 2012). In addition, lifestyle interventions can help to address any behaviours (such as drinking alcohol or poor nutrition) which may be worsening the mood symptoms associated with BD (Sarris, O'Neil, Coulson, Schweitzer, & Berk, 2014; Yarborough, Stumbo, Yarborough, Young, & Green, 2016). Recent research into the management and treatment of BD has been particularly concerned with understanding PA in BD, to incorporate lifestyle recommendations and manage mood symptoms, as well as to reduce the risk of developing physical health conditions (Bauer et al., 2016; Masa-Font et al., 2015; Sylvia et al., 2019; Sylvia et

al., 2013b; Yarborough et al., 2016). However, Stubbs et al., (2018c) conducted a meta review that identified the evidence concerning PA as a treatment in BD as limited. This may be due to a lack of understanding of PA and SB in BD more generally, as the focus in the existing literature has been on the effectiveness of exercise-based interventions (Masa-Font et al., 2015; Ng et al., 2007; Subramaniapillai, Goldstein, et al., 2016; Sylvia et al., 2013a; 2013b) rather than first exploring what it is like to engage in PA whilst living with BD. Furthermore, the evidence from systematic reviews have mostly considered the role of exercise in SMIs more widely (Williams et al., 2007; Pearsall et al., 2014; Stanton and Happell, 2014; Schuch et al., 2016a; Morgan et al., 2018) rather than specifically in BD (Bauer et al., 2016; Melo et al., 2016) and so the evidence concerning those living with BD is limited.

Some previous research has focused on evaluating the longitudinal effects of exercise interventions over time as a treatment of depressive symptoms in the general population (Danielsson, Noras, Waern, & Carlsson, 2013; Josefsson, Lindwall, & Archer, 2014; Kvam, Kleppe, Nordhus, & Hovland, 2016; Meyer, Koltyn, Stegner, Kim, & Cook, 2016; Sylvia et al., 2013a). It has therefore been suggested that exercise be included within the treatment plan of those with BD to help regulate mood symptoms, as well as to help reduce the risk of developing physical health conditions (Awick et al., 2017; Ekkekakis & Murri, 2017; Pedersen & Saltin, 2015; Vancampfort 2015g; Wright et al., 2009). However, exercise is only one form of PA, which is a planned, structured activity (Caspersen et al., 1985) and so, again, this research does not provide information on the relationships between mood and less structured PA (day-to-day activities), nor does it offer an insight into the relationship between PA and SB in relation to BD specific mood symptoms: BD depression or

(hypo)mania. Furthermore, a recent systematic review (Melo et al. 2016) of exercise in BD patients identified the lack of studies comparing exercise across mood states, concluding there is insufficient data to determine the relationship between mood and exercise specifically in BD. This is one of the most important limitations of previous research making recommendations concerning increasing PA or decreasing SB, as it is not clear how this relates to mood symptoms in people living with BD.

Identifying relationships between PA, SB, and mood in people with BD could improve the self-management of mood symptoms and assist future research into the aetiology and presentation of BD. Given the known relationships between PA, SB, and depression in the general population, examining these factors in BD is clearly warranted to support the future treatment and management of BD, by providing evidence of the relationships between PA, SB and mood symptoms in people living with BD. However, to understand PA and SB in BD for the purposes of assessing any relationships with mood symptoms, there is first a requirement to accurately measure PA and SB in BD to then be able identify any associations with mood symptoms.

2.6 Measuring physical activity & sedentary behaviour

This section provides a review of the various measurements of PA and SB available and debates the appropriate use of these various methods for use in an exploration of PA and SB in people living with BD.

With the increased interest in investigating PA and SB in various populations, there has also been a surge in the development and review of how to measure PA and SB (Aguilar-Farías, Brown, Olds, & Peeters, 2015; Bai et al., 2016; Calabró, Lee, Saint-Maurice, Yoo, & Welk, 2014; Gennuso, Matthews, & Colbert, 2015; Santos-Lozano et al., 2017; Soundy et al. 2014a; Tedesco et al., 2019), particularly in 'at risk' mental health populations such as BD (Faulkner, Cohn, & Remington, 2006; Merikangas et al., 2018; Vancampfort et al., 2016e).

Although there are several available options to consider when collecting data for the purpose of measuring and reporting PA and SB, they can be broadly categorised into either 'subjective' or 'objective or device-based' means of measurement (Prince et al., 2008; Prince et al., 2020). Subjective measures describe tools such as questionnaires or interviews and therefore rely on self-reported information from the participant (or their representative, e.g., a clinician or carer), whereas objective and device-based measures describe tools that do not rely on the memory of a participant, and take various readings (e.g. heart rate) to provide a measurement of PA and/or SB (Prince et al., 2008; Prince et al., 2020).

2.6.1 Subjective measures of physical activity & sedentary behaviour

Subjective measures are less accurate than objective or device-based measurements, as not only do participants have to rely on their memory, which may not be accurate, there is a risk of either overestimation or underestimation of behaviours (Bakker et al., 2020; Prince et al., 2008; Prince, LeBlanc, Colley, & Saunders, 2017; Prince et al., 2020; Soundy et al., 2014a). This risk increases the greater the time period for the recall (Prince et al., 2020) i.e., PA or SB will be less accurately recalled in a monthly rather than a weekly recall questionnaire. Research has also shown participants self-report PA and SB more accurately when recalling from a defined time period such as 'the last seven days' as opposed to using 'a typical week for you' format (Prince et al., 2020; Soundy et al., 2014a) which increases the accuracy of the self-report tool to represent what it is trying to measure, be it PA, SB, or both. It can be difficult for participants to accurately recall behaviour as structured activity such as exercise, work, and travel is typically easier to recall, whereas general PA (e.g. housework) or SB (e.g. watching television) is more difficult to recall as it is less structured (Aguilar-Farías et al., 2015; Matthews, Moore, George, Sampson, & Bowles, 2012; Wijndaele et al., 2014).

Self-report questionnaires are the most used subjective measurements of PA and SB as they can provide estimates of a population's PA or SB engagement using large samples of participants within shorter time periods, and are more cost-effective and less time consuming than interview-led questionnaires which require an individual or team of people to interview participants to collect the data (Prince et al., 2008). The benefits of interview-led questionnaires however are that the interviewer can support more accurate estimations by ensuring that responses do not exceed maximum values (for example over 24hrs a day) and by encouraging participants to

answer all questions within a questionnaire, reducing the likelihood of errors or missing data (Rosenbaum & Ward, 2016; Rosenbaum et al., 2020).

PA and SB questionnaires used in previous research (self-report or interview-led) have usually been validated against an objective or device-based measurement and/or a detailed activity diary or log to establish whether the two measures agree with each other, and therefore provide similar reporting of PA and/or SB, preferably within the population they are being used in; e.g. general population (Craig et al., 2003; Marshall, Miller, Burton, & Brown, 2010; Prince et al., 2008; Prince et al., 2020; Rosenbaum et al., 2020; Wanner et al., 2016) or mental health populations (Soundy, Taylor, Faulkner, & Rowlands, 2007). Bland-Altman Plots (Bland & Altman, 1986) provide a visual comparison between two measurements by plotting the mean of the two measures against the difference of the two measures. This identifies whether there is any evidence of bias in the questionnaire. If there is no consistent bias this indicates the questionnaire does not over or underestimate PA or SB and it is reasonable to assume the questionnaire provides a reasonably accurate calculation of PA and/or SB. However, a criticism of research attempting to validate PA/SB questionnaires is that it frequently only assesses the relationship between the two measures using correlation statistics, which only informs of the strength of the relationship between the two measures (if any), not how well they agree or if there is any potential bias (see Table 2.1 below). Overall PA and SB questionnaires have been widely criticised for either overestimating or underestimating PA and SB when compared to a device-based measurement such as an activity monitor (Prince et al., 2008; Soundy 2014a; Terwee et al., 2010).

Table 2.1 below presents a summary of questionnaire features for some of the most used PA and SB questionnaires with the published validation paper statistics. This

was created using information gathered from published research alongside questionnaires listed on the SBRN questionnaire database (sedentarybehaviour.org/sedentary-behaviour-questionnaires-), and questionnaires cited in the review articles of Prince et al. (2017) and Soundy et al., (2014a). As several questionnaires include a measure of both PA and SB, these are presented in the same table for easier comparison. Concurrent validity is reported as ‘r’ in the table as not all studies provided Bland-Altman plots for interpretation of agreement between the questionnaire and a device-based measure.

Table 2.1 Summary of commonly used physical activity & sedentary behaviour questionnaires

Questionnaire (alphabetical order)	No. items	Recall timeframe	Target population	Purpose	Method of administration/ completion	Concurrent Validity information (against a device-based measure)
7-day physical activity recall questionnaire (7DR)	4	Last 7-days	General population	To estimate leisure and occupational PA	Self-report	Blair et al., (1985) (r=0.21 to 0.45)
European Prospective Investigation into Cancer and Nutrition (EPIC)	4	Typical week in the last 12 months	Older adults	Relationships between PA and chronic disease	Self-report	Cust (2007) (r=0.21 to 0.29)
International Physical Activity Questionnaire (IPAQ)	Short item =7 Long item =27	Available for typical week and Last 7-days	General population	To estimate total time spent in vigorous, moderate, and low intensity PA and sitting time	Self-report or telephone interview	Craig et al., (2003) Long item: (r=-0.27 to 0.61) Short item: (r=-0.12 to 0.54)
Marshall Sitting Questionnaire (MSQ)	5	Unspecified (used as last 7-days)	General population	To assess sitting time across domains of SB	Self-report	Marshall et al., (2010): (r=0.13 to 0.74)
Occupational Sitting and Physical Activity Questionnaire (OSPAQ)	3	Last 7-days	Working population	PA and sitting time during work hours	Self-report	Chau, et al., (2012) (r=0.29 to r=0.65)
Sedentary Behaviour Questionnaire (SBQ)	9	Typical week	General population	To assess sitting time across domains of SB	Self-report	Rosenberg et al., (2010) (r= -0.005 to 0.26)
Simple Physical Activity Questionnaire (SIMPAQ)	5	Last 7-days	Mental health population	To assess PA and SB levels in mental health populations	Clinician/ health professional interview	Rosenbaum et al., (2020) (r=0.10-0.25)
SIT-Q-7D	20	Last 7-days	General population	To assess sitting time across domains of SB	Self-report	Wijndaele et al., (2014): (r= 0.21 to 0.76)
Yale Physical Activity Survey for Older Adults (YALE)	5	Last month	Older adults	To assess daily living in older adults	Interview	Gennuso et al. (2015) 8.5% agreement (concurrent validity not reported)

2.6.1.1 Physical activity questionnaires

Terwee *et al.*, (2010) published a comprehensive checklist for comparing and choosing a PA questionnaire for a particular purpose or researching a particular population: see Table 2.2 below.

Table 2.2 The Quality Assessment of Physical Activity Questionnaires (Terwee et al., 2010). Copyright permission obtained from Springer Nature February 2021

Property	Definition
1. Construct	What is the construct that the questionnaire intends to measure (e.g. energy expenditure, mechanical loading, walking)?
2. Setting	In what setting is PA measured (e.g. work, transport, leisure time)?
3. Recall period	What is the recall period to which PA is referred (e.g. past week, usually)?
4. Purpose	What is the purpose of the questionnaire (i.e. discriminative, evaluative or predictive)?
5. Target population	For what kind of people was the questionnaire originally developed (e.g. age, sex, health status)?
6. Justification	Why is this questionnaire needed and why is it superior to analogous questionnaires that may already exist?
7. Format	Are the number of questions, the number and type of response categories and the scoring algorithm clearly described?
8. Interpretability	Is there any information available on the interpretability of scores, e.g. are (mean/median and SD/range) scores and change scores available for relevant groups, e.g. age and sex groups from the general population? Is it known what an MIC in scores on the questionnaire are?
9. Ease of use	Is the time and effort required to complete the questionnaire acceptable? Is it known how a full copy of the questionnaire can be obtained? Are clear instructions given for those who need to complete the questionnaire?

MIC = minimal important change.

Given the various properties to consider, choosing an established questionnaire to measure PA in BD is challenging, as the questionnaire needs to be appropriate for use in the chosen population (format, ease of use, target population), and accurately

capture the PA within that population (construct, setting, recall period, purpose, justification, interpretability). Currently, there is no clear recommendation in the literature for using a particular PA questionnaire specifically in people with BD. From Table 2.1 above, the YALE and EPIC questionnaires can be disregarded as the target population is older adults, and it is important to first appreciate an understanding of PA in the wider BD population, before aiming to understand PA specifically in older adults living with BD. The 7DR, OSPAQ, and IPAQ were designed for use in the general population, and the SIMPAQ for use in mental health populations, and so all offer a relevant 'construct' in the absence of a specific PA questionnaire for use in the BD population. However, although the OSPAQ provides an easy-to-use questionnaire with comparability to activity monitors such as the ActivPAL by breaking down recall into time spent 'walking' and 'standing' (as well as 'sitting'), the target population is the general 'working' population and so is not suitable unless specifically investigating the BD working population. Given that those living with BD demonstrate lower levels of employment and have more days out of work than the general population (Alonso et al., 2011), the OSPAQ is not the most suitable tool for exploring PA in the wider BD population. Therefore, from the established questionnaires in Table 2.1, the 7DR, IPAQ and SIMPAQ are tools that may be appropriate for use in BD and are debated below.

Soundy, Taylor, Faulkner, & Rowlands, (2007) explored the validity of the 7DR for use in mental health populations, but found that the questionnaire consistently led to over-reporting of moderate PA by almost 17mins a day, and underreported vigorous PA by 10mins per day when compared against an accelerometer and examined using Bland-Altman plots (Bland & Altman, 1986) to determine agreement. However,

the study only included 14 psychiatric outpatients (unspecified diagnoses), not meeting the requirement of 50 for a validation study (Terwee et al., 2010).

The IPAQ is a 7-day recall questionnaire and is one of the most commonly used questionnaires in research exploring PA in BD (Branco et al., 2014; Fellendorf et al., 2017; Masa-Font et al., 2015; Vancampfort et al., 2015b). There is a short and long option for length, and these can either be self-administered or conducted as an interview over the telephone, providing four possible options for completion. The additional questions in the longer versions include items on transportation and work-related PA. All four options ask questions which relate to activity which has lasted more than 10mins and provide examples of what is regarded as vigorous, moderate, and low intensity activity. The purpose of IPAQ is to provide a means with which to measure and compare internationally gathered data on PA and so has been created to suit a wide age range of 15–69 year-olds and has been translated into multiple languages, and validated across twelve countries. There is a clear scoring protocol for the IPAQ to aid comparability between responses from various studies and populations. There is also a question relating to SB, however the overall focus for the questionnaire is on PA. The IPAQ is also one of the only questionnaires to ask questions about different intensities of PA (such as moderate and vigorous), which allow for more detailed comparison of PA levels against the recommendations outlined by the CMO PA guidelines. The IPAQ is a well-known, validated PA self-report tool for general population use which has also been used extensively in various mental health populations (Branco et al., 2014; Fellendorf et al., 2017; Melo et al., 2019; Perez-Cruzado et al., 2018; Stubbs et al., 2018a; Vancampfort et al., 2015f), whereas other questionnaires have been designed and validated with a specific population in mind, for example older adults (see Table 2.1).

Vancampfort et al., (2016e) argue that existing PA questionnaires need to be validated in BD specifically due to issues with their generalisability to those living with BD who can exhibit cognitive impairment, or different levels of activity which some questionnaires may be limited in capturing. Vancampfort et al., (2016e) therefore piloted a study for the validation of the IPAQ (Craig et al., 2003) for use in BD using the Sensewear Armband Pro. Only 20 participants were included, also not meeting the minimum of 50 required for a validation study (Terwee et al., 2010). It was however concluded that the IPAQ overestimated moderate (24mins) and vigorous (35mins) PA and underestimated total energy expenditure (945METS), and advised the IPAQ be used with caution in this population in the absence of a fully validated tool given its validity and wide use across the general population. Faulkner, Cohn, and Remington (2006) also conducted a validation of the IPAQ in those with schizophrenia (N=35) and reported moderate criterion validity (r=0.37) of total PA as measured by the IPAQ against an RT3 accelerometer, although agreement was not explored. Both of the above studies concluded that the IPAQ demonstrated similar levels of recall error as observed in the IPAQ in the general population (Craig et al., 2003, r=0.30) indicating that mental illness does not necessarily reduce the validity of a questionnaire's suitability when aimed at the general population. However, it is something that needs to be considered. For example, there is no reason to assume that people with BD are less able to accurately complete a PA or SB questionnaire simply because they have BD, which could be argued as discriminatory. However, during episodes of illness which elicit cognitive impairment, the ability to focus on activities is reduced (APA, 2013) which is a limitation that would apply to the completion of any PA or SB questionnaire. And so, whilst it is not without limitations, the IPAQ is still arguably the most suitable self-report PA tool which can also provide

data for comparison against other populations and studies. As the limitations of using the IPAQ to measure PA in BD are known, they can be considered in relation to the results of this PhD.

A more recently developed questionnaire for use in mental health populations is the SIMPAQ (Rosenbaum & Ward, 2016). SIMPAQ is an interview-lead questionnaire to be carried out by clinicians or researchers which can be conducted in person or via telephone. The questionnaire was designed to be a short, instant access tool to gain an overall picture of how much time a person is sedentary for, and how physically active they are, over either a single or seven-day period, with the aim that it will be implemented as a routine assessment tool within psychiatric practice (Rosenbaum and Ward, 2016). Aside from not being self-administered, one of the key differentiations from the IPAQ is that the SIMPAQ begins with questions relating to sleep, such as 'average napping time per day' followed by questions related to structured exercise and then non-structured activity, whereas IPAQ does not incorporate sleep at all. The SIMPAQ therefore attempts to gather a large amount of information on an individual's behaviour in very few questions, however the questions themselves rely on large estimates, and includes time 'sitting' and 'time napping' in the same calculation, despite SB and sleep being separate constructs with different energy expenditures (Tremblay et al., 2017). There is no clear outline of what constitutes vigorous or moderate PA, and what counts as a significant time frame for doing this, whereas the IPAQ has clearly defined definitions of what is meant by 'vigorous' and the activity is to have lasted ten minutes or more to be included. At the time of writing this review, and prior to undertaking any data collection for this PhD research, the SIMPAQ was still being explored to establish its validity, and so there was no evidence yet that the SIMPAQ would be a suitable tool

to use to estimate PA and SB in BD. Due to the lack of information on validity, the lack of breakdown on PA intensity, and that the SIMPAQ is an interview-led questionnaire making it impractical for large population studies which have to adhere to strict timeframes (such as a PhD research project); the SIMPAQ was not considered a suitable tool for exploring PA and SB in BD.

The data concerning concurrent validity of the SIMPAQ was added to this review and Table 2.1 above retrospectively. The validation study for the SIMPAQ was recently published (Rosenbaum et al., 2020) and identified that for those living with BD, the SIMPAQ demonstrated lower validity in the assessment of SB (r=0.04) when compared with schizophrenia (r=0.26) and depressive disorder (r=0.09), even after applying a correction to the SIMPAQ scoring of SB which aimed to try and strengthen the validity of SB assessment using SIMPAQ. In addition, on visual inspection of the Bland-Altman plots, MVPA showed decreasing agreement as the amount of time spent in MVPA increased, and several participant's data points fell out with the limits of agreement for both MVPA and SB assessment (Rosenbaum et al., 2020). This strengthens the initial conclusion that the SIMPAQ was not the most suitable tool to investigate PA and SB in BD.

In sum, the IPAQ is the most suitable tool for subjectively measuring PA in people living with BD despite its limitations. It provided the strongest criterion validity against a device-based measure in the general population, and there is some validity for its use in those with BD, and other mental health populations. The IPAQ can be easily distributed to large samples of participants and so is suitable for use in large population studies, providing comparable statistics to other studies also using the IPAQ, with a clear indication of what moderate and vigorous activity is.

2.6.1.2 Sedentary behaviour questionnaires

There is also no validated questionnaire for specifically measuring SB in people with BD. Of the questionnaires in Table 2.1, SB questionnaires which break down sitting time into domains across weekdays/weekend days over the last 7-days arguably aid ease of recall and reduce the likelihood of participant error, particularly as SB is typically less structured and more difficult to recall than PA (Clemes, David, Zhao, Han, & Brown, 2012; Marshall et al., 2010; Matthews et al., 2012; Wijndaele et al., 2014). Therefore, the questionnaires from Table 2.1 which estimate both PA and SB (e.g., IPAQ, SIMPAQ, and OSPAQ) are not suitable measures of SB for this PhD as they attempt to estimate SB with one question on total time spent sitting, and so offer little information on SB domains and may demonstrate a greater degree of recall error.

The SIT-Q-7D is arguably the strongest SB questionnaire in terms of collective validity which is not limited to a particular group or population. Unlike other validation studies of SB questionnaires carried out using hip or waist-worn accelerometers which need to be removed for bathing, potentially impacting on the accuracy of the data, the SIT-Q-7D was validated against an ActivPAL which is worn on the thigh with a waterproof dressing (and so does not need to be removed) with a large sample (N=452) (Wijndaele et al., 2014). Waist and hip-worn accelerometers may misclassify standing or light PA as SB due to inaccuracy in distinguishing between postures and lower intensity activity, whereas the ActivPAL is worn on the font upper thigh and is more able to detect changes to posture orientation (Alberto, Nathanael, Mathew, & Ainsworth, 2017; Calabró et al., 2014; Montoye, Pivarnik, Mudd, Biswas, & Pfeiffer, 2017). However, SIT-Q-7D is a lengthy questionnaire with 20-items, which may be a burden to participants and may lead to participants being less likely to

complete the questionnaire in full, particularly if experiencing mental distress or symptoms of mental ill health at the time of completion (Chapman, Fraser, Brown, & Burton, 2015b).

The MSQ (Marshall et al., 2010) is a shorter questionnaire of five items, which like the SIT-Q-7D, also breaks down sitting time into domains for weekday and weekend day and uses an 'average time spent' over the 'last 7-days' format. It showed reasonable validity against the ActivPAL activity monitor (Marshall et al., 2010) (see Table 2.1) and demonstrated stronger validity than the SBQ which uses a 'typical week' format (Rosenberg et al., 2010) which may elicit greater self-report recall error (Matthews et al., 2012; Prince et al., 2008).

There is currently no evidence of the validity or suitability of any questionnaire to estimate SB in people living with BD. In the absence of a validated tool, the MSQ is arguably the most suitable tool to begin a subjective exploration into SB in people living with BD as it showed acceptable validity against a thigh-worn monitor (in the general population), which provides a more accurate measurement of SB than hip/waist worn monitors. It is a short questionnaire which is not burdensome for participants to complete and uses a 7-day recall period for easier, more accurate recall, and breaks sitting time into domains to provide information on the SB being engaged with.

2.6.2 Objective and device-based measures of physical activity & sedentary behaviour

This section introduces and reviews the various objective and device-based measurements of PA and SB available. Objective measures include tools such as 'doubly labelled water' (DLW) (Prince et al., 2008), direct calorimetry (DC) and indirect calorimetry (IC), which are all used to calculate energy expenditure and are considered the 'gold standard' of PA/SB measurement (Alberto et al., 2017; Calabró et al., 2014; Evenson, Goto, & Furberg, 2015). DLW is consumed by a participant orally. Researchers are then able to determine how much energy has been used by measuring carbon dioxide production (Westerterp, 2017). DC obtains a measurement of heat generated from the body, and IC measures respiratory gas exchange (Prince et al., 2008; Tremblay et al., 2017; Trost, McIver, & Pate, 2005). However, DLW, DC, and IC methods are impractical, expensive, and burdensome to both participants and the researcher as they require continued observations and measurements. Further, they cannot be used to capture 'free living' PA and SB due to only measuring an isolated period of energy expenditure and so are not suitable for longitudinal research (Prince et al., 2008; Trost et al., 2005). Due to their limitations, these 'gold standard' objective measures are most often used to measure physical fitness or energy expenditure during bouts of exercise (Prince et al., 2008; Tremblay et al., 2017; Trost et al.,2005), or to validate device-based measures which can then be used to measure 'free living' PA and SB (Alberto et al., 2017; Calabró et al., 2014; Evenson et al., 2015; Lee, Kim, & Welk, 2014; Montoye, Pivarnik, Mudd, Biswas, & Pfeiffer, 2017; Prince et al., 2008; Santos-Lozano et al., 2017). Device-based measures include wearable tools such as step counters, heart rate monitors and fitness trackers (Alberto et al., 2017; Evenson et al., 2015; Naslund,

Aschbrenner, & Bartels, 2016; Yang, Schumann, Le, & Cheng, 2018). These tools take various readings at regular intervals, including heart rate, body posture (incline/ orientation), or bodily movements (acceleration) and capture the daily habits of a persons or populations PA and SB. Device-based measures can also be validated using detailed daily diary entries, direct observations, or comparing the readings of an existing validated device to the new device. (Trost et al., 2005).

Device-based measures are regularly referred to as 'objective measures' in the literature, however there is debate amongst researchers as to whether device-based measures should be considered 'objective' measures when compared to DLW and DC/IC (Aminian & Hinckson, 2012; Bueno-Antequera et al., 2018; Freyberg, Brage, Kessing, & Faurholt-Jepsen, 2020; Ostendorf et al., 2018; Scott, Vaaler, Fasmer, Morken, & Krane-Gartiser, 2017). This debate is due to the variation in the level of reliability and validity between different device-based measures meaning they are not as reliable as 'gold-standard' objective measures such as DLW, IC and DC (Kelly, Fitzsimons & Baker, 2016; Shephard 2017; Troiano, McClain, Brychta, Chen 2014). Device-based measures however are still more reliable than subjective measures such as questionnaires as they do not rely on participants self-reporting their PA/SB and are also more commonly used than DLW or IC/DC. This is due to the 'free living' format described previously, which means they are arguably able to capture a better representation of habitual PA/SB (Shepherd, 2017; Trost 2005). To reflect this on-going debate, over recent years there has been a shift in terminology within the PA/SB literature whereby the appropriateness of labelling device-based measures as 'objective measures' of PA/SB is challenged in favour of 'direct measure,' 'device-measure,' or 'wearables' (Alberto et al., 2017; Evenson et al., 2015; Naslund et al. 2016b; Naslund et al., 2016b; Prince et al., 2020; Sun et al.,

2020; Yang et al., 2018). To highlight this important distinction, the term 'objective measure' will be used in this thesis to describe accepted gold-standard measures such as DLW, DC/IC, and the term 'device-based measures' will be used to describe wearable activity monitors/ devices.

Table 2.3 outlines the features of the most used device-based measures.

Table 2.3 Feature summary of commonly used research-grade device-based measures

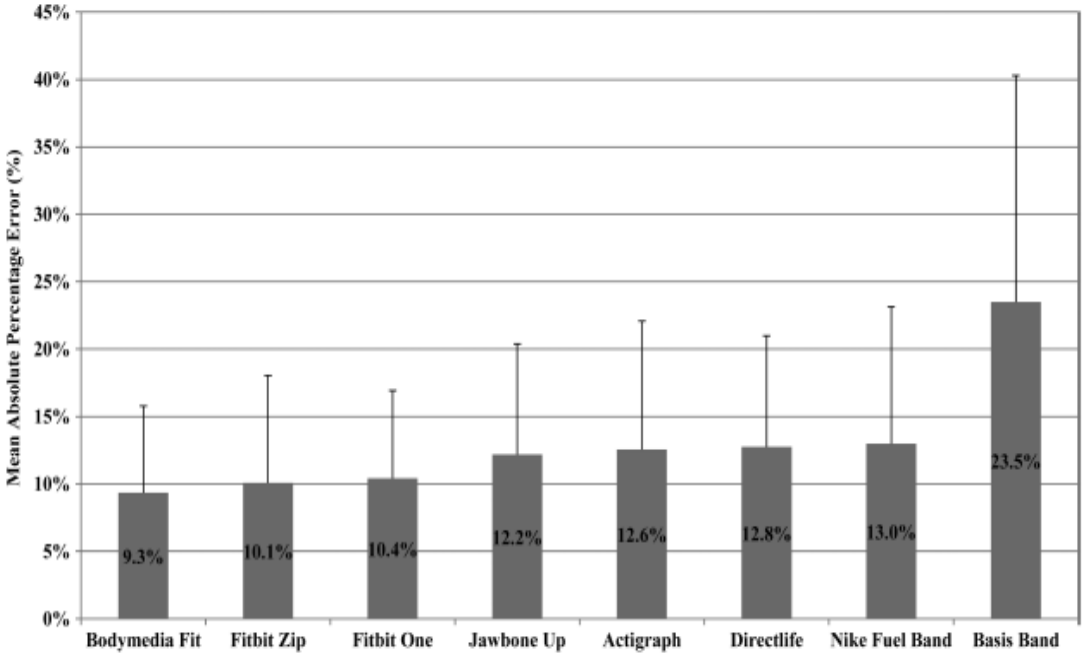
Device-based measure	**Measurement**	**Water resistant**	**Wear time**	**Sample rate (Hertz)**	**Body location**	**Weight/ dimensions**	**Validation Study(s) information**
Actigraph GT3X *(Actigraphcorp.com)*	accelerometer	Splash resistant	25 days	30-100 Hz	Waist, thigh, wrist, or ankle	Weight: 19g Dimensions: 4.6cmx 3.3cmx 1.5cm	***Indirect calorimetry:*** Crouter, Clowers, & Bassett, (2006); Santos-Lozano et al., (2013)
Actigraph GT9X (watch) *(Actigraphcorp.com)*	accelerometer	Yes	14 days	30-100 Hz	Wrist – with attachments for waist, thigh, or ankle	Weight: 14g Dimensions: 4.18cmx 3.98cmx 1.13cm	***Actigraph GT3X:*** Hwang, Fernandez, & Lu, (2018) ***Indirect calorimetry:*** Hibbing, Lamunion, Kaplan, & Crouter (2018)
Actiheart *(camntech.com)*	Accelerometer and heart-rate monitor	Yes	14 days	100Hz	Chest (attached with ECG electrodes or a strap)	Weight: 10.5g Dimensions: 39.7 x 30.3 x 9.25	***Indirect calorimetry:*** Crouter, Churilla, & Bassett, (2008); Barreira, Kang, & Caputo (2009)
ActivPAL *(Palt.com)*	Accelerometer: Inclinometer	Yes (waterproof dressing)	7 to 14 days	20 Hz	Thigh	Weight: 10g Dimensions: 23.5mmx 43mmx 5mm	***Indirect calorimetry:*** Montoye et al., (2017)
SenseWear Armband *(BodyMedia Inc.)*	Accelerometer, galvanic skin response and skin temperature	Splash resistant	4 to 5 days	Unable to obtain info	Upper arm	Weight: 85g Dimensions: 85.3mmx 53.4mmx 19.5mm	***Actigraph GT3X:*** Lee et al., (2014) ***Indirect calorimetry:*** Santos-Lozano et al., (2017)
Fibion *(Fibion.com)*	Accelerometer	Yes (waterproof dressing)	20-30 days	12.5 hz	Thigh, or can be placed in pocket	Weight: 20g Dimensions: 30mmx 32mmx 10mm	***Observation and indirect calorimetry (also compared to Actigraph GT9X):*** Yang et al., (2018)

There is currently no recognised ‘gold standard’ activity monitor (Trost et al., 2005). Many investigations of the accuracy of activity monitors have focused on their ability to determine energy expenditure during MVPA against IC, DC or DLW during periods of exercise (Prince et al., 2008 Santos-Lozano et al., 2017; Schneider & Chau, 2016) and there have been fewer explorations into the accuracy of activity monitors for determining sedentary or light intensity PA (Alberto et al., 2017; Calabró et al., 2014; Tedesco et al., 2019). However, given the few studies that have measured SB, or PA other than exercise (for example light PA) in people with BD, an activity monitor that provides an acceptable measurement of both PA and SB simultaneously would be required to capture the PA and SB of people living with BD, given the previous argument that device-based measures are more accurate than subjective measures. It is therefore important to determine which of the many available monitors is the most suitable by considering: what does the device need to measure? Does the device considered give an accurate measurement of PA or SB? And is the device practical for use in the population being explored and the structure/ setting of the study? (Trost et al., 2005).

Alberto et al., (2017) explored the criterion validity of three commonly used wearable activity monitors on energy expenditure in SB and light intensity PA featured in Table 2.3: ActivPAL, ActiGraph GT3X+ and the Sensewear Armband Pro 2. Of these, the ActivPAL had greater overall accuracy for determining SB and light PA, demonstrating the lowest mean percentage error (9.3%-14.9% v >21.2%). However, Calabró et al., (2014) compared the Sensewear Armband, Sensewear Mini, ActivPAL, Actiheart and Actigraph GT3X against IC to determine which most accurately assesses light intensity PA and found the Sensewear Mini provided the most accurate estimate of energy expenditure (4% mean percentage error). The

ActivPAL demonstrated lower mean percentage error only to the Actigraph GT3X (22.2% v 25.5%) in the study.

Lee, Kim and Welk (2014) and Bai et al., (2016) both compared the validity of commercially available wearable activity monitors with research-grade monitors. Figure 2.2 and 2.3 below provide the mean percentage error of the investigated devices in these studies.

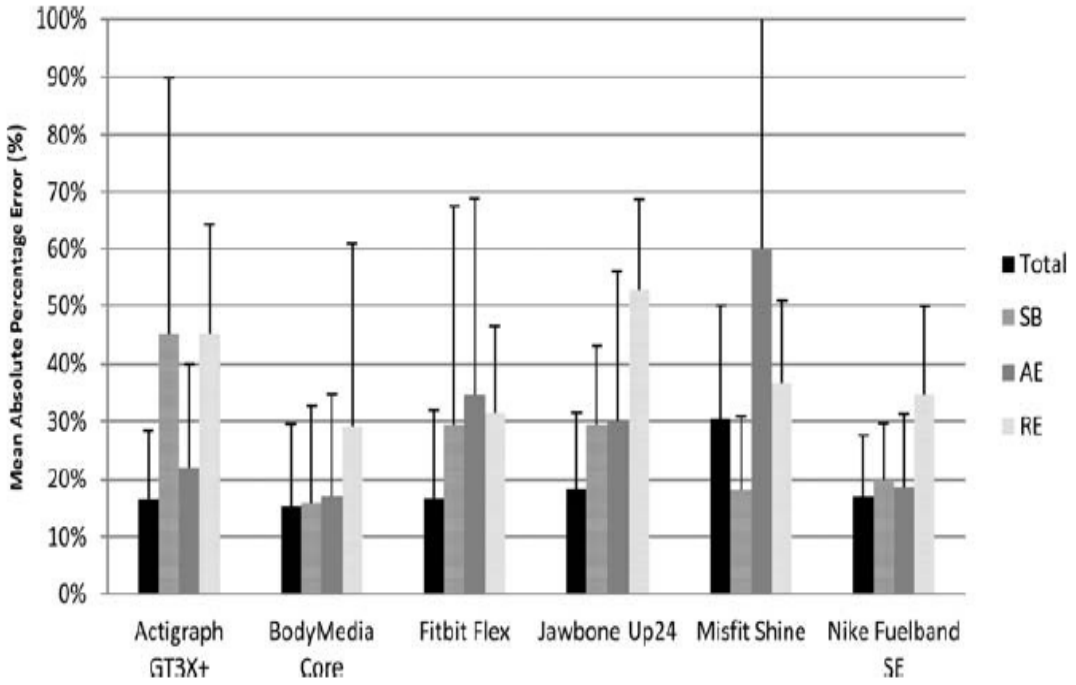


—Mean absolute percentage error (±SD) for all monitors with measured REE (n = 60).

Figure 2.2 Mean percentage error of wearable activity monitors investigated in Lee, Kim & Welk (2014). Copyright permission obtained from Wolters Kluwer February 2021

Figure 2.2 above shows that all wearable activity monitors investigated by Lee et al., (2014), except the Basis Band, showed acceptable validity against IC. A strength of the Lee et al., (2014) study was that it used a 'free living' structure (N=60 participants) whereas Bai et al., (2016) asked participants (N=52) to complete certain

activities to determine how well the activity monitor identified and differentiated between different intensity activities.



SB = sedentary behaviour, AE=aerobic exercise, RE= resistance exercise

Figure 2.3 Mean percentage error of wearable activity monitors investigated in Bai et al., (2016). Copyright permission obtained from Wolters Kluwer February 2021

Figure 2.3 shows that although the most commonly used research-grade activity monitor, the Actigraph GT3X+, shows a low mean percentage error overall, it is much more effective in identifying aerobic exercise than SB or resistance exercise (Bai et al., 2016). Furthermore, the Actigraph GT3X+ showed the highest mean percentage error for SB compared with the other monitors the Bai *et al.*'s (2016) study, and was mid-range total mean percentage error for PA in Lee et al., (2014). The Actigraph GT3X+ is therefore arguably not the most appropriate method when attempting to measure PA *and* SB in people living with BD despite being one of the most commonly used monitors in PA and SB research.

The more recently developed Fibion device (Table 2.3) may be a suitable device for use in BD, however the validation statistics were not available at the time of completing this review and have been added to Table 2.3 retrospectively following the publication of the validation paper. Yang et al., (2018) found that when worn on the thigh, the Fibion offers similar validity as the Actigrah GT9X for PA. However, the sample size was small (N=19) and so further explorations are required, particularly in relation to light intensity PA and SB.

Overall device-based measures can be difficult to use in research exploring 'free-living' PA and SB due to the burden on participants' time, comfort and the cost associated with providing these devices to large samples of participants (Trost et al., 2005). There is also a risk that devices will stop recording due to a problem with the battery or the programming (Edwardson et al., 2015; Trost et al., 2005), or that the participant does not return the device resulting in data loss. Furthermore, recommendations for the number of valid days required to estimate 'free living' habitual PA and SB vary, and are debated from being as little as a couple of days to a full week (Chapman, Brown, & Burton, 2015a; Chau, Van Der Ploeg, Dunn, Kurko, & Bauman, 2011; McVeigh et al., 2016; Trost et al., 2005; Winkler et al., 2016). It has been identified as good practice to ask participants to keep a sleep log whilst wearing an activity monitoring device to record sleep and any removal of the device to try to prevent the misclassification of data and determine valid wear time (Chapman et al., 2015a; Edwardson et al., 2015; McVeigh et al., 2016; Trost et al., 2005; Winkler et al., 2016). For example, if someone removed their device for an hour, the device may record the participant as being sedentary during this time even though this was not the case. This can be amended using the information from a sleep and device removal log. As with subjective measures, relying on the accuracy

of participant memory for sleep and device removal times each day is still a limitation to the accuracy of the output from the activity monitor, however completing a log can also increase compliance with wearing the device (Trost et al., 2005). Devices which do not need to be removed for showering, bathing, or sleeping (see Table 2.3) are therefore favourable for gaining a more accurate account of activity in people with BD, reducing the reliance on self-reported sleep and removal logs as wear time and sleep can be more accurately determined if the device is never removed.

Researchers must consider the cost and practicality of using the chosen activity monitor for the population being studied. Research where device-based measures have been used have considerably smaller sample sizes as a result, (Prince et al., 2008; Prince et al., 2020; Trost et al., 2005) and so although they are more accurate than using subjective measures such as questionnaires, they arguably do not provide transferable or generalizable results for the chosen population due to the smaller sample size. Whilst device-based methods are more reliable for quantifying time spent in PA and SB, they are impractical for large-scale and longitudinal research as they are expensive and require some training in how to use them, both for the researcher and the participant, and the participant has to remember to put it on every day for a given period if it is not waterproofed (Prince et al. 2008; Trost et al., 2005).

A considerable limitation to using only device-based measures however is that activity monitors provide no domain related data. Although subjective measures are considered less accurate, the previous section identified that some capture information on the type of PA or the intensity of the PA, or provide a breakdown of the domain of SB engagement that contributed to their total time spent in SB. The type of SB undertaken may offer important information relevant to the population

under investigation. For example, knowing if a participant was sitting whilst socialising with friends rather than watching television could be helpful to describe and explain the trends or patterns of a populations' behaviours surrounding SB in relation to other factors such as physical or mental health. Therefore, any device-measured exploration into PA and SB levels in people with BD should include a subjective measurement of SB to establish time spent in different domains of SB as they have been identified as a highly sedentary population (despite the use of arguably inappropriate methods to determine SB), and little is known about their sitting behaviours.

Although there is some support for commercially available monitors being used in research, including their use as motivational and engagement tools for increasing PA in mental health populations (Naslund, Aschbrenner, Barre, & Bartels, 2015; Naslund, Aschbrenner, & Bartels, 2016a; Naslund, Aschbrenner, Scherer, et al., 2016b), the evidence on their accuracy in determining PA and SB is still limited (Bai et al., 2016; Evenson et al., 2015; Lee et al., 2014; Schneider & Chau, 2016) and so research grade monitors (such as those in Table 2.3) are the most suitable option for measuring PA and SB in BD. In sum, the ActivPAL is the smallest, flattest device from Table 2.3 and so is the most discrete and least invasive device for estimating 'free living' habitual PA and SB (particularly when compared with the Actiheart which is worn on the chest). The ActivPAL can also be waterproofed, rather than being merely splash proof, reducing the issues associated with establishing wear-time and relying too heavily on self-reported sleep and removal logs. The ActivPAL also demonstrated improved measurements of SB and light PA than traditional hip and wrist worn accelerometers (Alberto et al., 2017), and uses a lower sampling frequency which can reduce the bias observed in higher sampling frequencies which

include a greater number of activity counts (Kruisdijk et al., 2017; Trost et al., 2005). Given that those living with BD have been identified as being less active and more sedentary than the general population (Elmslie et al., 2001; Janney et al., 2014; Shah et al., 2007), the ActivPAL is arguably the most suitable tool for measuring PA and SB in people living with BD as it is better at detecting lower intensity activity and SB.

2.7 Exploring physical activity & sedentary behaviour in bipolar disorder

The previous section highlighted that PA and SB can be measured subjectively or using wearable activity monitoring devices. This has contributed to limitations such as a lack of comparable measures, small/mixed population samples, and a lack of generalisability in previous research exploring PA or SB in BD (see Table 2.4 below).

Whilst there has been ample research exploring PA and SB in populations that exhibit depression (Schuch et al. 2016a; Schuch et al. 2016b, Teychenne et al. 2010; Zhai et al. 2015), people with BD experience depression *and* (hypo)mania mood symptoms and could therefore exhibit different levels of engagement with PA and/or SB than people who only experience symptoms of depressed mood (Krane-Gartiser et al., 2017; Krane-Gartiser, Asheim, Fasmer, Morken, & Vaaler, 2018b; Merikangas et al., 2018; Scott, Vaaler, Fasmer, Morken, & Krane-Gartiser, 2017; Melo et al. 2016; Vancampfort et al. 2016b). There is also evidence to suggest that symptoms of depression present differently in those with BD than symptoms of depression in the general population due to the significant level of impairment during an episode and the episodic nature of BD (APA, 2013; Cuellar, Johnson, & Winters, 2005). Explorations into PA, SB and mood specifically in people living with BD are

therefore vital for determining the relationship between PA, SB and BD depressive symptoms.

Two systematic reviews explore exercise in BD (narrative reviews): Bauer *et al.*, (2016) included 6 studies with BD participant sample sizes of 1 to 57, and focused on reviewing lifestyle interventions incorporating exercise, whereas Melo *et al.*, (2016) included 31 studies which included a measurement of exercise in BD, with sample sizes of BD participants ranging from 5 to 9522. The larger sample sizes in this review were taken from self-reported cross-sectional research, rather than device-based measures of exercise, and the self-reported exercise was not collected using an established tool (such as those listed in Table 2.1), but generic questions on exercise engagement which are not validated and are difficult to compare across studies (Cairney, Veldhuizen, Faulkner, Schaffer, & Rodriguez, 2009; Chwastiak, Rosenheck, & Kazis, 2011; Kilbourne et al., 2007; Sylvia et al., 2013a). Both reviews on exercise in BD concluded that further research was required to establish the role of exercise in BD, and to establish the relationship with mood symptoms (Bauer et al., 2016; Melo et al., 2016) due to inconsistencies in the research findings and generally small sample sizes preventing unified findings from across the included studies.

One systematic review explored PA and SB in people with BD (Vancampfort et al., 2016a), and found people with BD spent on average 10hrs 13mins a day in SB, and 3hrs 30mins a day being physically active, which was not significantly different to healthy control groups. Another systematic review included mixed samples of those with BD, schizophrenia and major depressive disorder (MDD) (Vancampfort et al., 2017b), and found that people with BD were more sedentary (10hrs 15mins) than those with schizophrenia, MDD, or control groups, but were also engaged in more

MVPA (1hr 24mins) and were more likely to meet the CMO guidelines than the other diagnoses. Another systematic review explored SB in people with psychosis (Stubbs, Williams, Gaughran, & Craig, 2016) which included 2033 participants, of whom only 60 participants from one study had BD (Janney et al., 2014) and so there was insufficient evidence on the amount of time people with BD spent in SB in the review. More recently, Shuichi Suetani, Stubbs, McGrath, and Scott (2019) conducted a systematic review on PA levels in those with an SMI compared to the general population, but included no breakdown of the amount of PA BD participants engaged in, and Bort-Roig et al.,'s (2020) systematic review on SB in those living with an SMI also provided no break-down of SB time for BD participants. These systematic reviews highlight that the evidence concerning the amount of time people with BD spend in PA and SB remains limited, with inconclusive results. A possible reason for this is the lack of studies that consider the impact of the episodic nature of BD by exploring any association between the time spent in PA and SB and symptoms of (hypo)mania, compared with depression, mixed state, and euthymia (Krane-Gartiser, Henriksen, Morken, Vaaler, & Fasmer, 2018a; Krane-Gartiser et al., 2017; Merikangas et al., 2018; Scott et al., 2017). An earlier systematic review explored correlates of PA in people living with BD (Vancampfort et al., 2013) and found evidence of medical co-morbidity being associated with lower PA, as well as evidence of lower BMI and older age being associated with lower PA levels. However, Vancampfort et al., (2013) also concluded more evidence on these variables was required, and that overall there was a lack of information on any association between psychiatric variables (e.g. length of BD illness) and PA in the literature.

Furthermore, most of the evidence regarding PA and/or SB engagement in BD has been extracted from studies with mixed population samples, including: BD, schizophrenia, unipolar or major depressive disorder and anxiety disorders, and/or small samples of people with BD (Chuang et al., 2008; Chwastiak et al., 2011; Krane-Gartiser et al., 2018a; 2018b; Kilbourne et al., 2007; Masa-Font et al., 2015; Strohle et al., 2007; Stubbs et al., 2016). There are some published studies of PA (mostly exercise) in BD specifically (Cairney et al. 2009; Elmsie et al. 2001; Janney et al. 2014; Jewel et al. 2015; McGlinchey et al. 2014; Vancampfort et al. 2015a; 2015d; Vancampfort et al. 2016b; 2016c), however few studies include a measurement of SB (Janney et al., 2014; Jewell et al., 2015; Vancampfort et al., 2016e). Table 2.4 below summarises the research which has included a measurement of PA and/or SB in people living with BD. Where the study included mixed population samples, the data and conclusions (where possible) regarding BD have been extracted for the table.

Table 2.4 Summary of original research exploring PA and/or SB in people living with BD

Study Reference (in date order)	Sample size (BD)	PA and/or SB measured?	Method (objective/ device-based/ subjective or intervention)	Measure of mood?	Conclusions
(Elmslie et al., 2001)	N=89	PA	Subjective: Life in New Zealand Questionnaire: (LINZ) questionnaire which asks about occupational and leisure PA over last month	None	People with BD self-reported less PA engagement than matched controls
(Ng et al., 2007)	N=35 (14 in intervention)	PA	Intervention: 40mins daily walk offered to inpatients	Depression	Preliminary evidence of PA improving general wellbeing in BD
(Strohle et al., 2007)	N=39 start, N=18 at four year follow up	PA	Subjective: (interview) four questions asked: do you exercise? do you engage with any sports? what kind of sports? And how frequently do you exercise?	None	Incidence of BD higher in those engaged in regular PA

Study Reference (date order)	Sample size (BD)	PA and/or SB measured	Method (objective/ device-based/ subjective or intervention design)	Current mood state measured	Conclusions
(Kilbourne et al., 2007)	N=2032	PA	Subjective: questions asked on how often 1. walked outside for 20 min or longer 2. engaged in strength exercise for at least 20 min.	None	People with BD are at a greater risk of physical ill health due to poor diet and lack of PA
(Shah et al., 2007)	N=14	PA: exercise	Objective: participants ran on treadmill until exhaustion. Echocardiogram completed before and after (analyses heart function and blood flow)	None	Participants with BD engaged in exercise on a treadmill for significantly less time than controls.
(Chuang et al., 2008)	N=60	PA: exercise	Subjective: data taken form Canada's health promotion survey (specific questions not published)	Depression	Low engagement of exercise not limited to diagnostic group: 14% total sample (not just BD) reported never engaging in vigorous exercise, and up to 77% reported only engaging in SB activities.
(Cairney et al., 2009)	N=831	PA: exercise	Subjective: Canadian Community Health Survey- questions asked on activities engaged in, frequency and duration over last three months	None	Levels of self-reported PA levels are not significantly lower than in the general population
(Chwastiak et al., 2011)	N=9522 (veterans)	PA	Subjective: asked how often do you engage in regular activities (e.g., brisk walking, jogging, bicycling, etc) long enough to work up a sweat?	None	Veterans with BD at greater cardiovascular risk due to physical inactivity
(Proudfoot et al., 2012)	N=198	PA: exercise	Subjective: participants asked about changes to exercise in relation to mood triggers	None	A decrease in exercise activities associated with onset of a depressive episode in BD
(Sylvia et al., 2013a)	N=482	PA: exercise	Subjective: participants asked about frequency of exercise	Depression and (hypo)mania:	Depression is associated with less exercise and mania with more exercise in BD
(Sylvia et al., 2013b)	N=5	PA: exercise	Intervention: delivery of an exercise module as part of an intervention programme	Depression and (hypo)mania	A module delivery intervention may improve exercise engagement and mood symptoms in people with BD.

Study Reference (in date order)	Sample size (BD)	PA and/or SB measured?	Method (objective/ device-based/ subjective or intervention)	Measure of mood?	Conclusions
(McGlinchey et al., 2014)	N=32	PA	Device-based: Actiwatch and subjective: self-reported daily exercise engagement	Depression and (hypo)mania	No PA differences found between a control group and those living with BD
(Janney et al., 2014)	N=60	PA and SB	Device-based: Actigraph	Depression only	People with BD more sedentary and less active than matched controls
(Branco et al., 2014)	N=1953	PA	Subjective: IPAQ	Depression and (hypo)mania	25.3% participants reported regular PA engagement, and male participants were significantly more active than females
(Masa-Font et al., 2015)	Unpublished (N=240 mixed sample)	PA	Intervention and subjective: IPAQ	Neither	The intervention carried out increased PA engagement.
(Jewell et al., 2015)	N=86 (adolescents)	PA & SB	Subjective: 17-item Quick Weight, Activity & Excess Screener (WAVE)	Depression and (hypo)mania	Adolescents with BD less likely than controls to engage in sufficient levels of PA
(Vancampfort et al., 2015a)	N=19	PA (to determine cardiorespiratory fitness)	Objective: 6min-walk test, cardiopulmonary exercise test (cycling – ergometer bike)	Depression	Age, weight, and 'negative' mood explained 70% of variance in cardiorespiratory fitness
(Vancampfort et al., 2016d)	N=22	PA	Subjective: IPAQ	None	PA participation lower in people with BD than controls
(Vancampfort et al., 2016b)	N=65	PA	Subjective: PAVS assessment	Depression	BD patients not meeting 150mins PA weekly may be at increased risk of cardio - metabolic diseases and reduced capacity for exercise.
(Vancampfort et al., 2016e)	N=20	PA & SB	Subjective: IPAQ Device-based: Sensewear armband pro	None	The IPAQ may be used as a tool to assess PA in people with BD, however further research into the validity of this tool in BD is required due to small sample size.

Study Reference (in date order)	Sample size (BD)	PA and/or SB measured?	Method (objective/ device-based/ subjective or intervention)	Measure of mood?	Conclusions
(Metcalfe et al., 2016)	N=30 (adolescents)	PA: exercise	Objective: 20mins of cycling followed by fMRI scan	Depression and (hypo)mania	Exercise engagement may initiate biological changes to brain that may offer insight into aetiology of BD and presentation of depressive symptoms.
(Subramaniapillai et al., 2016b)	N=32 (adolescents)	PA: exercise	Objective: 20 min bout exercise on cycle ergometer Subjective: Exercise-Induced Feeling Inventory completed before and after exercise.	Depression and (hypo)mania	Adolescents with BD experience similar post-exercise improvement in mood as controls
(Scott et al., 2017)	N=34	PA	Device-based: Actiwatch for 24hrs	Depression and (hypo)mania (established prior to participation)	Actigraphy may be a tool for determining the presence of mania and depressive episodes in BD (through the monitoring of activity counts)
(Krane-Gartiser et al., 2017)	N=36	PA	Device-based: Actigraph	Depression and (hypo)mania (established prior to participation)	Those experiencing mania were significantly more physically active (particularly in the morning) than those with depression.
(Merikangas et al., 2018)	N=54	PA	Device-based: Actigraph	Overall mood (ecological momentary assessment)	Energy levels may impact on subsequent mood and activity levels in BD
(Krane-Gartiser et al., 2018a)	N=18	PA	Device-based: Actigraph	Mania (established prior to participation - all patients in mania episode)	BD patients experiencing mania showed less regularity in activity patterns compared to those with schizophrenia.
(Krane-Gartiser et al., 2018b)	N=3 (case-series)	PA	Device-based: Actigraph	Case 1 = mania Case 2 = mixed state Case 3 = depression, the mania	Actigraphy offers a personalised approach to the monitoring and treatment of mood episodes.

Although there is evidence from Table 2.4 to suggest people with BD are more sedentary and less active than the general population (Elmslie et al., 2001; Janney et al. 2014; Jewell et al., 2015; Melo et al. 2016; Shah et al., 2007; Vancampfort et al. 2016d), some research has concluded that people with BD are no less active than the general population (Cairney et al., 2009; McGlinchey et al., 2014; Vancampfort et al., 2016a). This difference in research findings may be due to the overwhelming use of self-report tools that may not be capturing any differences accurately as the previous section identified that PA and SB are often either over or underestimated when compared with device-based measures (Prince et al., 2008; Prince et al., 2020; Soundy et al., 2014a).

Of the research which investigated PA and/or SB in BD using a subjective measure, only Branco et al., (2014), Masa-Font et al., (2015), Vancampfort et al., (2016b), and Vancampfort et al., (2016e) used an established, validated subjective measurement (IPAQ and PAVS). Although these studies used established, validated questionnaires, Vancampfort et al., (2016b); and Vancampfort et al., (2016e) had small sample sizes, Masa-Font et al., (2015) used a mixed population sample of participants with multiple diagnoses without distinguishing the PA and SB engagement in those with BD specifically, and Branco et al., (2014) used the IPAQ to categorise participants into simple ‘active’ or ‘inactive’ categories using cutoffs not validated or recommended within the IPAQ scoring protocol (Craig et al., 2003). Furthermore, Cairney et al., (2009), Chuang et al., (2008) and Elmslie et al., (2001) used data from population based surveys created specifically to collect large amounts of data from multiple areas of interest (e.g., diet, exercise, lifestyle, etc.), whereas Chwastiak et al., (2011), Jewell et al., (2015), Kilbourne et al., (2007), McGlinchey et al., (2014), Strohle et al., (2007) and Sylvia et al., (2013a) used

unvalidated questions/questionnaires to establish time spent in PA and/or SB and so are severely limited as they offer little information on PA and SB engagement, and no replicability or comparability with other studies. These studies also contributed the most data which was included in the meta-analyses and systematic reviews on PA and SB explorations in BD (Bauer et al., 2016; Melo et al., 2016; Stubbs et al., 2016; Vancampfort et al., 2016a; 2017b), and so the majority of evidence to support what is currently known about PA and SB in BD is therefore based on the use of subjective, self-report tools. If the tools used in previous research are not the most valid estimation of PA and SB for the BD population, the conclusions drawn from the research could become invalid. Further investigation into PA and SB in BD using evidence based subjective and device-based measurements of PA and SB that are suitable for use in BD is warranted to highlight any differences between the PA and SB levels identified in previous research, particularly research which has created a PA or SB questionnaire to use (i.e. studies whose measurement of PA or SB was not collected using an established, validated questionnaire). Including a subjective measurement of PA or SB such as a questionnaire alongside a more accurate, device-based measure of PA and SB is still helpful for obtaining valuable contextual information on the behaviours of each participant whilst they are wearing an activity monitor, and also offers an opportunity to validate a questionnaire against an activity monitor to establish whether there is agreement between the measures. However, from Table 2.4 McGlinchey et al., (2014) used unvalidated questions regarding the type of exercise engaged in, and Subramaniapillai, et al., (2016b) asked participants to complete the ‘exercise-induced feeling inventory’ which focuses on feelings following exercise rather than the type of exercise enagged with. Vancampfort et al., (2016e) asked participants to complete the IPAQ alongside wearing an activity

monitor (Sensewear armband pro), to validate the IPAQ for use in BD. Although the purpose of this study was to explore validity, the IPAQ offers no context on SB engagement, and for PA provides information on the intensity of the activity enagaged in, rather than the type of PA, which is already collected from the activity monitor.

The previous section identified that objective and device-based measures provide more accurate measures of PA and SB than subjective measures, however several studies from Table 2.4 which have used an objective or device-based measure of PA in BD have only examined the effects of a single bout of exercise to measure physical fitness in relation to health-outcomes (Metcalfe et al., 2016; Shah et al., 2007; Subramaniapillai et al., 2016b; Vancampfort et al., 2015a), rather than providing a measurement of 'free living' PA in BD. Although this research is helpful for determining physical fitness and understanding the link between physical fitness and physical health outcomes, it does not provide information on habitual PA which is required to understand the real-life assessment of day-to-day PA and SB in people living with BD. Although Vancampfort et al., (2015a) were able to establish a number of factors which were associated with lower cardio-respiratory fitness such as weight, and symptoms of depression, which regular PA engagement may help to regulate in this population, this does not provide evidence on PA or SB engagement day-to-day.

Although some of the previous research in Table 2.4 used device-based measures to quantify time spent in PA and/or or SB under free-living conditions, these were limited by relatively small sample sizes of people with BD (Krane-Gartiser et al., 2017; Krane-Gartiser et al., 2018a, 2018b; McGlinchey et al., 2014; Scott et al., 2017; Shah et al., 2007; Vancampfort et al., 2016e). Janney et al., (2014), however did manage to recruit 60 participants with BD to wear an Actigraph on the hip for 7-

days to monitor PA and SB in BD outpatients against matched controls, concluding adults with BD are less active and more sedentary than the general population. In contrast, McGlinchey et al. (2014) found no significant differences of PA (measured using an Actiwatch) in 32 BD participants compared with controls. Although Actigraphs are considered suitable for measuring PA, they are limited in measuring posture orientation and light intensity activity (Calabró et al., 2014) which is required to distinguish SB from light-intensity activity. Therefore, this is not the most accurate tool for measuring SB in BD, particularly when compared to the ActivPAL (palt.com) which is specifically designed to measure SB. This is a severe limitation to the field and to date Janney et al.,'s (2014) study provides the largest device-based measurement of SB specifically in people with BD.

More recent device-based explorations of PA in BD from Table 2.4 have shown an increased interest in understanding the activity patterns of people with BD across different mood states (Krane-Gartiser et al., 2017; Krane-Gartiser et al., 2018a; Merikangas et al., 2018; Scott et al., 2017) although SB remains largely unexplored both as a standalone construct, and in relation to mood episodes in this population. Krane-Gartiser et al., (2017) established that BD participants experiencing mania were significantly more active in the morning than those experiencing depression, and then Krane-Gartiser et al., (2018a) found that although participants with schizophrenia and BD participants experiencing mania presented similarly in their clinical presentation, the BD participants engaged with more irregular levels of activity and less routine PA behaviours, highlighting the need for further explorations into PA in BD to understand any irregularity. This research has offered some evidence that actigraphy has the potential to identify key differences in the presentation of depressive, (hypo)manic and mixed mood states in BD, however SB

is not reported on in relation to the PA and mood associations, two of these studies had considerably small sample sizes of 3 (Krane-Gartiser et al., 2018b) and 18 (Krane-Gartiser et al., 2018a), and the studies used wrist-worn actigraphy which is more susceptible to error compared with thigh and hip worn devices as they are less able to accurately distinguish sitting from standing behaviours (Calabró et al., 2014; Montoye et al., 2017).

Exploring PA and SB in BD independently is required to distinguish relationships which are specific to this population, including possible relationships with mood symptoms that are largely uncharacteristic of other diagnoses. Although the more recent research from Table 2.4 has recognised the importance of considering mood symptoms specific to BD in relation to PA measurements in this population, most of the earlier studies investigating PA or SB in people with BD have only included people with BDI or very few with BDII (Janney et al., 2014; McGlinchey et al., 2014; Shah et al., 2007; Vancampfort et al., 2015d), and so BDII is largely underrepresented. As people with BDII do not experience full-blown mania, there may be different relationships between PA and/or SB and mood between those with BDI and BDII and this also warrants investigation. Despite this, Table 2.4 showed that few studies include a current measurement of mood at all, and several only include a measurement of depression symptoms. Kilbourne et al., (2007) for example recruited a large sample of 2032 participants with BD to subjectively explore exercise and nutrition and concluded that people living with BD were more likely to self-report ‘poor exercise habits’ including ‘infrequent walking’ compared with those living with schizophrenia, or those with no SMI, as well as inconsistent eating habits and weight gain. However, infrequent walking is more an indication of low PA levels rather than low exercise, and no other aspects of PA were considered in this

study, and so it is limited to a poor measurement of exercise engagement. Although it is acknowledged that Kilbourne et al., (2007) did not necessarily aim to explore mood in relation to exercise and nutrition, there is no measurement of current mood state in this cross-sectional study to determine any connection between these variables; despite changes in weight, appetite and general activity also being in the DSM criteria for a BD mood episode (APA, 2013).

In addition, several studies which collected a measure of current mood state used this to identify euthymic participants or those experiencing 'sub-threshold' symptoms for participation in their research rather than using these data to explore mood in relation to PA or SB (Fellendorf et al., 2017; McGlinchey et al., 2014; Melo et al., 2019; Shah et al., 2007). It is therefore unclear if there are differences in the relationships between PA and SB with (hypo)mania, and PA and SB with depression.

Furthermore, it is also unclear how the identified relationships between PA, SB and depression in the general population (Stubbs et al., 2018b; Suetani et al., 2019; Teychenne et al., 2010) are present in those with BD who also experience (hypo)manic symptoms. This is particularly important, as the few studies from Table 2.4 which have attempted to explore (hypo)manic symptoms in relation to specific exercise in BD produced mixed and inconclusive results (Ng et al., 2007; Sylvia et al., 2013a; Wright et al., 2012). Only a couple of the more recent studies offered an exploration of (hypo)manic symptoms and PA more widely than experiences of exercise, however in one of these only manic patients were recruited and so no comparison was made to symptoms of depression, and the sample size was small (Krane-Gartiser et al., 2018a), and in another, although a device-based measure

was used, data were collected over only 24hrs, and again in a small sample (Scott et al., 2017) and so is unrepresentative of the BD population.

Ng et al. (2007) identified a decrease in the severity of depressive symptoms in BD following participation in a regular walking group. However, the small sample were all inpatients who were therefore considered to be in recovery, and not in a typical 'free living' environment; there was no direct measure of PA; and mania symptoms were not assessed. Proudfoot et al. (2012) identified relationships between decreased physical exercise and depressive episodes in BD using a mood episode triggers survey, however this was retrospectively explored, and no current measure of mood was included. Sylvia et al. (2013a) found associations between increased exercise and manic symptoms, although did not record details of the intensity of exercise, for example whether this was MVPA, resistance training, or light PA. As this research has been inconclusive and has provided no evidence of the direction and strength of any relationship between PA, SB and mood, further research is required. By simultaneously monitoring mood symptoms, PA, and SB it will be possible to identify which aspects of PA and SB, if any, are associated with specific mood symptoms. Considering that increased energy and activity levels are in the diagnostic criteria for a (hypo)manic episode, and that decreased levels are in the diagnostic criteria for a depressive episode (APA, 2013), understanding relationships between all aspects of mood and all aspects of PA and SB in BD to identity if PA and/or SB are associated with specific mood symptoms (Krane-Gartiser et al., 2017; Krane-Gartiser et al., 2018b; Merikangas et al., 2018; Proudfoot et al., 2012).

Research from Table 2.4 has also been limited by mostly cross-sectional designs exploring PA and/or SB at one point in time rather than gathering several days of data to explore so that there is more than one measure of PA and/or SB to examine

per participant (Branco et al., 2014; Cairney et al., 2009; Elmslie et al., 2001; Vancampfort et al., 2015d). To more fully understand relationships between PA, SB, and mood in BD, gathering data on each of these variables over several days may help to identify relationships between PA, SB, and mood more reliably than only considering a one-off measurement. (Hypo)manic episodes are less frequent and do not usually last as long as depressive episodes (APA, 2013) meaning that high mood symptoms can be particularly difficult to identify in one-off measurements within cross-sectional research, particularly in small samples. This has further contributed towards the lack of research into PA, SB, and the expression of (hypo)manic symptoms in-particular, alongside the previously identified exclusion of participants experiencing (hypo)manic symptoms in previous research.

Overall the evidence concerning PA levels, and the impact of PA in relation to BD mood symptoms can be considered as limited (Cairney et al., 2009; Ng et al., 2007; Vancampfort et al., 2016a; Vancampfort et al., 2016b). More research is needed to identify relationships between PA and mood in people with BD other than exercise, since exercise is a structured activity specifically engaged with to keep fit, however PA refers to all physically active behaviours, not just those engaged with for exercise. Considering that breaking up SB is a key recommendation of the CMO guidelines, and the associations of SB with poor mental health (Teychenne et al., 2010, 2015; Zhai et al., 2015) and physical health (Proper et al., 2011; Shields & Tremblay, 2008), it is important for research to consider the role and impact of PA in BD more widely than exercise, as SB can be reduced without having to engage in exercise by being more physically active and moving more. It was also acknowledged that few studies include a measurement of SB in BD, and those that have arguably used an inappropriate activity monitor to assess SB (Janney et al.,

2014) and have provided little contextual information on the type of SB being engaged with (Jewell et al., 2015). Considering the identified need to decrease SB engagement in this population (Chuang et al., 2008; Janney et al., 2014; Vancampfort et al., 2017b), this is vital information which is missing from the current literature.

2.7.1 Perceptions of physical activity, sedentary behaviour & mood in bipolar disorder

As well as attempting to identify and measure relationships between PA, SB and mood in BD, it is also important to consider the PA, SB, and mood relationship from the perspective of people living with BD to understand if what is being measured is also reflected in the experiences of people living with BD. This may also be useful knowledge for informing and improving the use of PA within the treatment and self-management of BD, and to reflect on the effectiveness of current PA recommendations and their feasibility within this population, by considering any limitations or considerations of PA and SB in relation to mood.

Qualitative research has considered the perceptions and experiences of PA in mental health populations. Participants in this research have included those diagnosed with schizophrenia (Firth et al. 2016b; Soundy, Stubbs, Probst, Hemmings, & Vancampfort, 2014b), depression (Pickett, Kendrick & Yardley, 2017) and BD (Wright et al. 2012). However, most qualitative research exploring experiences of PA and mental illness have included participants from mixed population samples including major depression, schizophrenia and BD (Hargreaves, Lucock & Rodriguez 2017; Mason & Holt, 2012; McCartan et al. 2020). For example, Hargreaves, Lucock, and Rodriguez (2017) interviewed eight participants with a diagnosis of either BD or schizphrenia and conducted a thematic analysis which

resulted in three main themes being created of 'not ready to engage,' 'initial steps to engaging in PA,' and 'becoming more active.' Hargreaves, Lucock and Rodriguez concluded that patients in recovery who were able to meet their PA preferences (i.e their preferred activity) were more motivated to continue to engage in PA. Mason and Holt (2012) provided a qualitative synthesis of PA across mental health populations and present several themes which help explain shared motivations and experiences of PA across diagnoses. These themes highlight a benefit from social interactions, gaining a sense of meaning/ purpose from PA, the importance of facilitating persons to support PA engagement, feeling safe, improved symptoms, and gaining a sense of identity. Most recently, McCartan et al (2020) published a qualitative synthesis identifying factors which influence PA engagement in those living with anxiety, depression, or related disorders (including obsessive compulsive disorder and post-traumatic stress disorder) and presented similar findings to Mason and Holt (2012). McCartan et al.'s (2020) review highlighted barriers for PA engagement which were shared across various mental health populations, including: low motivation; medication effects; cost; access to services; inexperience/lack of confidence, and a lack of understanding/awareness of how PA may help improve symptoms. Also highlighted were shared experiences of the motivations for engaging in PA, these included: mood management; improved sleep; improved physical health and fitness; and gaining a sense of achievement. Although useful for gaining a broad understanding of shared experiences across mental health populations, the Mason and Holt (2012) and McCartan et al. (2020) reviews do not offer in-depth information on different experiences between groups, or on experiences of PA in relation to symptoms such as mania or psychosis, and very few studies include participants with BD.

Previous qualitative research has also rarely considered the perceived relationships between PA engagement and mood, regardless of the mental health population being explored. Pickett, Kendrick, and Yardley, (2017) explored how, why and when PA may benefit depression, and reported participants moving from 'having to' to 'wanting to' engage with PA when they realised it made them feel better, however only two people from this sample of 26 had BD. Firth et al., (2016b) aimed to explore the perceived effects of exercise during participants' first experience of psychosis through a thematic analysis of interviews carried out with a sub-sample of participants from a wider study: iBeep (investigating the Benefits of Exercise in Early Psychosis). They reported that exercise was viewed as a tool to improve mental health and confidence by participants, and the theme of 'exercise alleviating psychiatric symptoms' highlighted participant perceptions that exercise helped distract from auditory hallucinations, overcome depressive symptoms such as a lack of energy and motivation, and were a facilitating factor in gaining a sense of achievement and improved wellbeing. Given that many people with BD experience psychosis at some point during their lifetime (APA, 2013), and experience symptoms of depression, qualitative research into exercise and schizophrenia gives some insight into the relationship between exercise and mood in people with BD. However, the only participant with BD within the iBeep study was not included in the interviewed sub-set, and people with BD are often minimally represented in research exploring PA in participants with a history of psychosis despite the symptom comorbidity with schizophrenia (Firth et al., 2016b; Quirk et al., 2017; Watkins et al., 2019). Therefore, although this research is helpful for contextualising the relationship between exercise and symptoms such as psychosis and depression, it does not help

in the understanding of experiences of mania and exercise, or exercise in the context of an episodic mood disorder.

The qualitative research which has explored PA specifically in BD has mostly reviewed the effectiveness of specific lifestyle interventions incorporating PA (often specific exercise), and focusses on the opinions of the participants or the facilitators in relation to the intervention (Bauer *et al.*, 2018; Çelik Ince and Partlak Günüşen, 2018; Hoffmann *et al.*, 2015; Quirk *et al.*, 2017; Searle *et al.*, 2012; Searle *et al.*, 2014; Watkins *et al.*, 2019; Way *et al.*, 2018). These findings therefore evidence participant views and reflections on a shared, structured experience where the aim was to review perceptions of a PA intervention, rather than PA engagement.

Bauer et al., (2018) investigated participant expectations of participating in a lifestyle intervention from the perspective of those living with BD by conducting a focus group and paired interviews (N=10). Participants commented on the need to be considered stable to benefit from specific lifestyle interventions, and that exercise should be an important part of such an intervention, as well as, and in relation to: medication; a healthy diet; and creative activities. This is indicative that exercise is perceived to play a part in the regulation of symptoms and prevention of full-blown mood episodes. This is echoed by Gerber *et al.*, (2016) who reviewed the provision of a form of PA in Swiss inpatient psychiatric settings, and concluded that specific exercise was perceived as an effective treatment in people with major depression when stable on medication and accompanied by psychological support to overcome the challenges of behaviour change and in maintaining this.

Wright et al., (2012) provide the only research exploring perceptions of a form of PA and mood using a UK sample (N=25) of people specifically with BD. Participants

were recruited via community advertisement and so provide a population based sample which is not limited to psychiatric inpatient settings. The study explored experiences of exercise and mood in BD using an interpretative phenomenological analysis (IPA). The three key themes which emerged were ‘regulating exercise for mood regulation,’ ‘bringing structure to chaos,’ and ‘exercise as a double-edged sword.’ The results identified mixed perceptions, particularly within the theme of ‘exercise as a double-edged sword’ as participants expressed that they felt exercise could be both helpful and harmful in relation to mood, particularly in relation to symptoms of mania, e.g., exercising too much would elevate mania. It was concluded that further research into exercise and specific mood symptoms is required to try to understand exercise and mood more pertinently in BD, as previous research has focused solely on depression (Chuang et al., 2008; Ng et al., 2007; Schuch et al., 2016b; Shah et al., 2007; Wright et al., 2009). As the study only explored experiences of exercise, there is an absence of information on the perceived relationships between how day-to-day PA and mood symptoms in BD may be related, as well as a lack of information on the experiences of the UK population of people living with BD.

Furthermore, there is no research to date exploring perceptions of SB and mood symptoms specifically in BD, despite research highlighting that people with BD are more sedentary than the general population (Elmslie et al., 2001; Janney et al., 2014; Shah et al., 2007; Vancampfort et al., 2015h) and that engaging in a high level of SB is a risk factor depression (Teychenne et al., 2010; Zhai et al., 2015).

2.8 Conclusions

In conclusion, whilst attempts have been made in previous research to explore some aspects of the relationships between PA, SB and mood symptoms in BD, there are several limitations to this research, and so further investigation is required.

The direction and strength of the relationships between PA, SB and mood in BD remain unclear. Previous research has been complicated using various subjective and device-based measurements of PA and SB that are not the most suitable tools for this population; making it difficult to generalise and compare the results, and to be confident the measures used provide the most accurate accounts of PA and SB.

Furthermore, little is known about the relationship with BD mood symptoms in relation to both PA and SB. Most studies which have explored PA and/or SB in BD have not considered the relationship with mood directly and have been limited by mixed population and/or small sample sizes, with very few comparisons made between those with BDI and BDII who experience different severities of (hypo)mania symptoms and illness patterns. The literature is lacking in mood data pertaining to BD depression *and* (hypo)mania under natural, free-living conditions (i.e., not inpatients taking part in treatment or an intervention, or relating to a single bout of exercise). Previous research has mostly been concerned with identifying and classifying PA and SB levels in people with SMIs collectively, where BD is one sub-group explored to establish the relationship between PA and SB and physical and mental health, rather than the relationship with mood specifically, despite this being a defining characteristic of BD.

There is support for increasing PA levels and reducing SB as a form of alternative treatment and self-management of mood in BD (Masa-Font et al., 2015; Ng et al.,

2007; Schuch et al., 2016b; Sylvia et al., 2013a; Sylvia et al., 2013b), although the evidence for this mostly relates to the improvement of depressive symptoms and exercise and is not necessarily specific to BD, with little knowledge on the roles or impact of (hypo)mania symptoms. Furthermore, there is no evidence of the perceived relationships between SB and mood symptoms in people living with BD, and limited evidence of perceptions of PA and mood other than specific exercise. Given that some participants felt exercise in particular is both a help and a hindrance for high mood (Wright et al., 2012), understanding the role of day-to-day PA and SB in relation to both high and low mood is vital, particularly in terms of the real-life presentation of this relationship, i.e. not only what is measured, but what is perceived by people living with BD. If PA and/or SB are associated with specific mood symptoms or mood episodes, this will be important information for the treatment and self-management of BD (Merikangas et al., 2018; Proudfoot et al., 2012; Scott et al., 2017) and warrants further investigation.

Understanding the relationships between PA, SB and mood could provide many benefits. Firstly, evidence on any associations between different PA intensities and types of SB with BD mood symptoms, and by extension, evidence on the suitability of PA or exercise interventions being applied to those with BD. Secondly, to support research exploring the presentation and aetiology of mood symptoms and mood triggers in BD. Finally, to aid the self-management of mood symptoms for those living with BD.

The combination of the identified gaps in the existing literature in addition to the limitations of previous literature conducted to date formed the overarching research question for this PhD research and the specific aims used to answer this question.

2.9 Research question

‘What are the relationships between physical activity, sedentary behaviour, and mood, in people living with bipolar disorder?’

2.9.1 Research aims

1. To explore the perceived relationships between all forms of PA, SB, and mood by interpreting the views and personal experiences of people living with BD.
2. To explore the relationships between device-measured PA, SB and self-reported daily and weekly mood symptoms in people living with BD.
3. To explore the validity of the Marshall Sitting Questionnaire for use as a self-report 7-day recall tool for estimating SB from sitting time in people living with BD.
4. To explore the relationships between subjectively measured, self-reported PA, SB and depressive and (hypo)manic mood symptoms in a large sample of people living with BD.

3 Chapter Three: Method

3.1 Philosophical underpinning of this PhD

It is the view of the researcher that the most appropriate way to address a research question is not necessarily to pick methods that align with a particular philosophical framework or paradigm, or underlying belief about the world and how it should be examined, but to pick the method(s) which most fully answer the research question, whether that be quantitative, qualitative, or an integration of both. Therefore, the completion of this research project was not set upon with a pre-made decision on how the research question should be explored to produce the most meaningful answer(s). This came from reviewing the literature (see Chapter two) identifying the limitations and unexplored areas of previous research, and subsequently focusing on the best way to answer each aspect of the research question. It was also important to consider how that information could be collated to provide an overall response to the research question without the presentation being fragmented or disjointed.

In a discussion of mixed methods paradigms, Feilzer (2010) complements the above views by suggesting that a pragmatic approach is one which focusses on the need to find the most appropriate way to address a research question, whist recognising the benefit of combining multiple research methods to provide multiple perspectives and present the most ‘socially useful’ knowledge. Doyle, Brady, and Byrne (2016) suggest a pragmatic approach allows researchers to dismiss the ‘false’ assumed dichotomy of research being solely quantitative or qualitative, when the research question cannot be answered by using one singular method. In the context of this PhD research, it was considered important to provide ‘socially useful’ knowledge on the relationships between physical activity (PA), sedentary behaviour (SB), and

bipolar disorder (BD) mood symptoms by highlighting research outcomes that may inform practice in terms of the treatment and self-management of BD, PA and SB health messaging, and potentially useful information for interventions aiming to increase PA and reduce SB in the BD population.

Mixed methods research approaches are often situated within a positivist or post-positivist framework or paradigm (Giddings & Grant, 2006; Hall, 2013; Holden & Lynch, 2000; Mertens, 2012). Positivism refers to the view of 'cause and effect,' and assumes outcomes are predictable (Giddings & Grant, 2006; Hall, 2013). Post-positivism suggests that 'cause and effect' predictions are complex, and that it is important to take into consideration the presence of, and integration of, other related factors; rather than assuming a linear 'cause and effect' predicted outcome (Braun & Clarke, 2019a; Giddings & Grant, 2006). Giddings and Grant (2006) present the theory that mixed methods approaches can align to any theoretical or philosophical framework, as long as the researcher has made clear their 'worldview,' i.e. their beliefs about what can be observed, measured and understood about the world through the process of research. The worldview incorporates perceptions of what is reality (ontology), what is knowledge (epistemology), how knowledge should be gained (methodology) and ones values (axiology) (Aliyu, Singhry, Adamu, & Abubakar, 2015; Giddings & Grant, 2006; Hall, 2013; Mertens, 2012). Furthermore, Giddings and Grant, (2006) and Giddings, (2007) warn that the absence of a pre-defined philosophical framework or paradigm does not mean that there are no assumptions about the world underpinning choices in research. In consideration of this, and the above discussed definitions of positivism, post-positivism, and pragmatism within mixed methods research; it is acknowledged that the researcher's worldviews can be considered aligned with accounts of post-positivism, and follow a

pragmatic approach to decision making regarding the design, method and interpretation of results within this PhD research.

3.2 Mixed methods in research

There is debate over the appropriateness and application of mixed methods research (Giddings, 2007; Johnstone, 2004; Morse, 2005; Tashakkori & Creswell, 2007). Debate surrounds the philosophical frameworks or paradigms typically associated with qualitative and quantitative research, with some researchers arguing that mixed methods research does not work due to the different ontology or 'truths' that underpin either method, and how these guide the way researchers explore their topic and make sense of it (Symonds & Gorard, 2010). However, combining qualitative and quantitative methods is deemed acceptable, and often necessary, when the research topic is complex, there is limited or inconclusive evidence from previous research using either approach, and when words and numbers interplay throughout the research process (Bowling, 2014; Johnstone, 2004; Mason, 2006). More recently, Shorten and Smith (2017) describe mixed methods research as a way of allowing the exploration of 'diverse perspectives,' and as being particularly helpful for answering 'multifaceted research questions.' Further, they argue that integrating qualitative and quantitative data provides a more holistic interpretation of data, by considering the wider context and multiple perspectives and allowing for the comparison of connections and differences between data collected for the same purpose. This is supported by the views of Doyle et al., (2016) and Molina-Azorin (2016) who describe mixed methods as a way of addressing multifaceted research questions which cannot be answered with one singular method.

For mixed method approaches to be suitable it is important that the research question can be answered in full or in part using both qualitative and quantitative methods. For example, trying to answer a research question on 'what it is like to *experience* having a blood test', by interviewing participants about their experience (qualitative), and then examining the results of the test itself (quantitative) would be an inappropriate use of a mixed methods approach as examining the results of the blood test does not contribute to understanding the *experience* (Giddings & Grant, 2006). In order to address the research question for this PhD thesis, an exploration into the perceived relationships between PA, SB and mood answered the research question from the perspectives of people living with BD (qualitative) and subjectively measured and device-measured PA and SB explored relationships between PA, SB and mood to statistically examine the strength and direction of relationships (quantitative). A mixed methods design was considered the most suitable way to approach the research question as both qualitative and quantitative methods contributed to answering the research question.

3.2.1 The suitability of mixed methods for this PhD

Chapter two identified that there was little information on any perceived relationships between PA, SB and mood from the perspective of people living with BD. It was important to include participant perceptions in this PhD to consider the real-life presentation and impact of personal and potentially complex experiences of living with a mood disorder, in relation to PA and SB. Given the limited information on this topic there would have been a large risk involved in creating a questionnaire to explore this as assumptions would have had to have been made regarding what was considered important and relevant to measure, with limited information to draw on from previous research. Exploring perceptions of something as personal and

complex as a mood disorder in relation to PA and SB therefore felt more appropriate to address through a qualitative exploration. This allowed flexibility to ask open questions and gain insight into what it is like to engage in PA or SB when living with a mood disorder, and to pick up on any evidence of a perceived association between PA, SB and mood.

Chapter two also identified that there were limitations concerning the accurate reporting of PA and SB in people living with BD which required further exploration to establish any statistically significant associations between PA, SB and mood. Objective measures were identified as the gold standard measurement of PA and SB available (Soundy *et al.*, 2014a), followed by device-measured PA/SB using wearable activity monitors. Both of these provide an opportunity to explore the validity of available self-report measures. However, it can be infeasible to use activity monitors with large sample sizes due to their cost and/or the time required to recruit large samples of people to use them as well as explaining how to use them (Naslund et al., 2016a; 2016b; Prince et al., 2008; 2020; 2017). Self-report measures can be easily distributed and used to measure PA and SB in large samples, and can provide detail on domains of activity unavailable from device-based measures (Branco et al., 2014; Cairney et al., 2009; Chekroud et al., 2018; Kilbourne et al., 2007). However, in a systematic review which examined self-report, subjective measures compared with device-based measures, it was concluded that self-report measures typically either overestimate or underestimate PA compared to device-based measures (Prince et al., 2008), and another systematic review identified that SB is typically underestimated compared with device-based measures (Prince et al., 2020).

Given that quantitative methods do not provide detail of personal experiences and reflections on any relationship between PA, SB and mood, and using only qualitative

methods would not provide statistical evidence of the relationships between PA, SB and mood, neither approach of looking at only subjective or device-based measures, (quantitative) or only exploring the perception of those living with BD (qualitative) would have individually and sufficiently answered the research question. However, adopting a mixed methods approach meant that the research question could be explored from the perspective of people living with BD, but also statistically explored using reliable measures of PA and SB. Exploring perceived relationships also allowed opportunity to follow up on areas of interest that may otherwise have been overlooked, for example, relationships between particular forms of PA or SB and aspects of mood. It also provided an opportunity to compare the evidence of statistically examined relationships (from device-based/subjective measurements of PA and SB) to how these relationships are perceived and experienced by participants.

The research question was therefore explored using a mixed-methods approach, integrating qualitative and quantitative data at various stages during the research process, with a final discussion of the combined results of three studies:

Study one: qualitative + study two: quantitative → integration

+ study three: quantitative → integration

Each study was designed to answer the research question from a different perspective: that of persons living with BD, and what could be observed though device-based and subjective measurements of the variables.

3.3 Discussion of qualitative methods

Chapter two highlighted the need for a qualitative study to explore perceived relationships between PA, SB and mood. As the qualitative study was part of a wider mixed-methods PhD thesis, it was important that the qualitative aspect of the research also complemented the quantitative aspects of this PhD by providing real-life accounts of the relationship between PA, SB and mood that could be used to help make sense of and interpret the data obtained from device-based and subjective measurements of these relationships.

Qualitative methods such as Grounded Theory and Interpretative Phenomenological Analysis (IPA) were not considered to provide the flexibility required for this research. IPA can be a time consuming and in-depth method that would not have complemented the other aspects of this PhD given the need to also measure PA and SB within the timeframe of a PhD, and which would not independently answer the research question to provide transferable results that could contribute to socially useful knowledge. However, narrative discourse and content analysis were methods not considered to provide enough depth and opportunity for interpretation to address the research question. Furthermore, Grounded Theory is a systematic approach undertaken with the purpose of creating or contributing towards theory, with the literature review following the research, rather than underpinning it (Glaser & Strauss, 1965), whereas this PhD is underpinned by a literature review was already directed from existing theory and research which have used a variety of methods. For example, Wright et al., (2012) used IPA; Pickett et al. *(*2017) used Grounded Theory, whereas Bauer et al., (2018) used a narrative approach.

Thematic analysis offered a flexible yet detailed approach to addressing the research question, whilst building on the existing accounts of knowledge published in previous research. Thematic analysis complemented the explorations of device-based and subjective measurements of PA, SB and mood within this PhD, and allowed for meaningful comparisons to take place between what is 'perceived' and what was 'measured' regarding the relationships between PA, SB and BD mood symptoms.

Braun and Clarke's (2006) widely used (Braun & Clarke 2019a; Clarke & Braun, 2018; Firth et al., 2016b; Mason & Holt, 2012; Watkins et al., 2019) six-step guide for conducting thematic analysis (the reporting of themes and patterns within interview data) was chosen to analyse the qualitative data of this research:

1. **Familiarisation of the data:** *transcribing data, reading and re-reading the data, noting down initial ideas.*
2. **Generating initial codes:** *coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.*
3. **Searching for themes:** *collating codes into potential themes, gathering all data relevant to each potential theme.*
4. **Reviewing themes:** *checking if the themes work in relation to the coded extracts, and the entire data set, generating a 'thematic map' of the analysis.*
5. **Defining and naming themes:** *ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.*
6. **Producing the report:** *the final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.*

Braun & Clarke's (2006) method was chosen for its flexibility, as they claim, *'thematic analysis is not wedded to any pre-existing theoretical framework'* (page 81), but is a way of reporting *'events, realities, meanings, and experiences'* within data that can align with most philosophical paradigms/frameworks. The six-step process is a

systematic but guided approach only to qualitative analysis rather than a rigid process which must be adhered to, to provide meaningful analysis of the data. This process includes becoming familiar with the data, and then coding the data by assigning a descriptive (semantic) or interpretive/analytic (latent) comment that captures what is important and relevant about that piece of data. These codes are grouped together to form themes in an iterative, reflexive process. Braun and Clarke's (2006) method describes theme creation as something that *'captures something important about the data in relation to the research question' (page 82)* and dismisses the idea that themes *'emerge'* (page 80 & 96) or are *'discovered'* (page 80) within data, and instead recognises the role the researcher has in determining what is important about the data to make up a theme. The approach taken to thematic analysis impacts on the six-step process, particularly for theme creation. Approaches can be inductive by nature, where data are processed and considered using a 'bottom up' perspective, an approach often used to help create a more focused research question. With this approach themes may not necessarily answer existing research questions defined before the analysis was carried out, but instead provide a broad overview and description of all data. A deductive approach however is 'top down' in nature, whereby the data are coded and themed in relation to aspects of the data that are of particular interest. This approach is more interpretative, rather than descriptive, focussing on aspects of the data that relate to the topic areas of interest to interpret their meaning, and was a more suitable approach for this PhD.

During the development of this PhD thesis, Braun and Clarke published further guidance and reflections on using thematic analysis to inform better practice of the method (Braun & Clarke, 2016, 2019a). Braun and Clarke's (2019a) paper highlights

consistently observed issues with researchers integrating thematic analysis with other, established, qualitative methods (namely grounded theory), or mistakenly trying to find a 'right' answer through their approach to theme creation, rather than taking ownership and reflecting on the subjectivity and process of qualitative research. Braun and Clarke (2019a) recommended their method be renamed *'reflexive'* thematic analysis to encourage researchers to question their work and highlight their reflections on the process of theme creation, particularly at step 4 where potential theme names (or 'candidate' themes) should be reviewed and questioned repeatedly. In encouraging more reflexivity, Braun and Clarke (2019a) argue that researchers can then better recognise the active role they have played in theme creation (including any underlying assumptions about the world which may have surfaced during the process of coding). Further, with added transparency, researchers strengthen their analytic interpretations by moving away from theme names founded in the topic guide (or 'domain' theme names) to theme names which tell us something unique about the data and its meaning (Braun & Clarke, 2016, 2019a). Despite this shift, Braun and Clarke's most recent reflections on their updated, reflexive, approach to thematic analysis highlight on-going difficulties in researchers' application of reflexive thematic analysis and the search for 'right-ness' or 'coding reliability' rather than an acknowledgement of subjectively and being transparent about what was done, and why (Braun & Clarke 2021). To better account for Braun & Clarke's most recent work following the completion of this thesis, and to be mindful of these criticisms of the application of thematic analysis, information highlighting the researcher's personal background, interests and motivations were added to appendix S.

For the qualitative aspect of this PhD, focus was maintained by considering Srivastava and Hopwood's (2009) framework for qualitative analysis. When compared with Braun and Clarke's (2006) original paper, Srivastava and Hopwood's (2009) framework is a complementary addition that summarises the key points of Braun and Clarke's (2006) paper into three questions: 1. What is the data telling us? 2. What is it we want to know? 3. What is the relationship between what the data is telling us, and what we want to know? This framework heightened the ability to ask questions of the data to meet the aims of this PhD. The third question in particular was important for considering how the qualitative exploration aided the interpretation of the results of the quantitative studies in this PhD research.

3.4 Discussion of quantitative methods

Chapter two also identified the need to incorporate both device-based measurements of PA and SB, and subjective measures of PA, SB and mood symptoms in this PhD research.

3.4.1 Device-based measurement

The available device-based and device-based measurements of both PA and SB were introduced in the previous chapter (see chapter two). Gold standard objective measures such as doubly labelled water (DLW) and direct and indirect calorimetry (DC/IDC) were concluded as being burdensome to both participants and the researcher and cannot be feasibly used to measure 'free living' PA and SB over several days or using a 24/h protocol. It was acknowledged that examining relationships between PA, SB, and BD mood symptoms over a 7-day period (and therefore providing daily and weekly measures) would provide more evidence of the relationships between PA, SB and BD mood symptoms than a one-off measurement

using DLW or DC/IDC. Furthermore, as discussed in chapter two; self-report measures of PA, SB and mood symptoms mostly use a ‘last 7-days’ protocol, and so a device-based measure which could also collect data over 7-days and allow for meaningful comparisons and relationships to be statistically explored was more appropriate. This was particularly important to allow for the direct comparison between a self-report sitting questionnaire for estimating levels of SB with a device-based measurement of SB as per the PhD aims. The device-based measurement needed to be non-invasive and simple for participants to apply and use to reduce participant burden and reduce the likelihood of attrition over the 7-days. It also needed to be cost-effective for use in a PhD research project, whilst effectively measuring both PA and SB, and so wearable activity monitors were considered the most suitable device-based measure to use. Wearable activity monitors have been shown to be a feasible method for collecting PA and/or SB data in mental health populations, despite concerns of cognitive and social impairments that may impact on memory and learning in relation to using an activity monitor (Naslund et al., 2015; Naslund et al., 2016a; 2016b). Given the need to be sure the activity monitor was suitable for research purposes (for example that it would not require charging during the 7-days for continuous monitoring, and would provide reliable, valid measurements of PA and SB to compare to previous research), only research-grade activity monitors (rather than consumable activity monitors such as Fitbit (fitbit.com)) were considered.

Chapter two highlighted several limitations in previous research attempts to measure PA and/or SB in people living with BD using device-based measures, including the use of specific activity monitors (and specifically their body placement) which are limited in successfully identifying light PA and SB, and argued that the ActivPAL

wearable activity monitor (Physical Activity Levels (PAL) Technologies, palt.com) is a more suitable device-based measure for this population, however it had not yet been used to quantify PA and SB in people living with BD.

As the ActivPAL3 is affordable, minimally invasive to wear, is flat and lightweight and therefore easy to post to participants, does not need to be removed for showering; and is a suitable research-grade activity monitor which is particularly effective for determining SB, the ActivPAL3 was chosen to provide the device-based measurements of PA and SB in this PhD. Furthermore, the ActivPAL3 does not provide live readings on the monitor and is worn discreetly and so whilst participants' activity may possibly still be impacted due to being aware they are wearing a monitor, they are not able to actively monitor this, and it is not in their line of sight day-to-day.

At the time of carrying out the PhD research, the ActivPAL3 was the most recent ActivPAL model available.

3.4.2 Subjective measurements

Chapter two also critiqued the various self-report tools used in previous research which aim to measure PA and/or SB. This section provides a more detailed report of the self-reported, subjective measures of PA, SB and mood chosen for this PhD research.

Physical activity

The International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) was chosen as the subjective self-report PA tool for this PhD research. The IPAQ offered the opportunity to explore relationships between self-reported PA intensities and BD mood symptoms in BD in a large sample using a validated, widely used tool which has previously been used in BD, offering comparability to other studies (Fellendorf et al., 2017; Masa-Font et al., 2015; Melo et al., 2019; Vancampfort et al., 2015b; Vancampfort et al., 2015f). The self-report last 7-days short version (7-item) was used so as not to over burden participants when completing multiple questionnaires (on PA, SB, and mood). The IPAQ short version took approximately 5mins to complete when tested.

The IPAQ normally concludes with a question on time spent sitting: *'during the last 7-days, how much time did you spend sitting on a week day?'* However, given that the current PhD research included a more accurate self-report SB tool (see below: The Marshall Sitting Questionnaire) that accounts for weekday and weekend day sitting, this question was removed from the IPAQ to avoid participant burden of providing the same information twice and/or influencing their response to one questionnaire due to completing the other. The IPAQ was therefore used as a 6-item questionnaire in this PhD (see Appendix A).

Sedentary behaviour

The Marshall Sitting Questionnaire (MSQ) (Marshall et al., 2010) (5-item) was chosen as the subjective self-report SB tool in this PhD. The MSQ asks for time spent sitting on a weekday and weekend day whilst travelling, whilst at work, whilst

watching television, whilst using a computer, and for leisure. The MSQ was chosen as it is a short, self-report questionnaire suitable for use in the general population with acceptable validity against device-based measures (see Table 2.1, page 29). Although the MSQ is not specifically described as being a 7-day recall questionnaire in the literature, the questionnaire was validated using data from a 7-day period of behaviour logs and activity monitoring using device-based measures (Marshall et al., 2010) and the phrasing of the questions do not specify that the questionnaire is to represent a 'typical week.' The questionnaire can therefore be used in a 7-day recall format. Previous studies using the MSQ have also used it in this format (Chau et al., 2011; Sasaki, Motl, & McAuley, 2019). The MSQ took approximately 5mins to complete when tested and so was not considered to be too long and burdensome for participants to complete, unlike the 27-item SIT-Q-7d questionnaire (Wijndaele et al., 2014).

The MSQ was used to gain domain related data for SB by exploring self-reported sitting times (hrs/mins) across weekday and weekend days. These were important data for exploring whether any relationships between SB and mood were dependant on the type of sitting, and therefore SB, being engaged with. The MSQ also provided context of SB which cannot be determined using the ActivPAL3, by allowing participants to also self-report their time spent in different domains of sitting during the 7-days that they wore the ActivPAL3. This allowed an opportunity to establish the level of agreement between the MSQ and the ActivPAL3, as there was no validated self-report tool SB tool identified with the literature review for use in BD (See Appendix B).

In discussion with PhD supervisors, it was acknowledged that the MSQ item 'sitting whilst using a computer at home' would potentially leave out other screen time from

technology which has advanced since the MSQ was published (Marshall et al., 2010) and are more commonly used, such as tablets, gaming consoles, smart phones etc. Therefore, the decision was made to make a small change to the wording of the 'whilst using a computer at home' to: 'sitting whilst using a screen' (not including whilst watching television e.g. using a computer/laptop/games console/ smartphone etc.), to reflect additional technologies that involve the same interaction with a screen as using a computer.

Daily mood

Daily mood measures are useful for capturing day to day changes in symptom severity. Daily measures are mostly used in clinical settings due to practical difficulties of collecting daily mood measures over a long period of time and managing attrition. However, including a measurement of daily mood for a short period of time allowed for relationships between daily mood and daily PA and SB to be explored within this PhD research with minimal risk of attrition.

Daily mood is most often logged on a chart, such as the National Institute of Mental Health 'Life Chart Method' (NIMH-LCM) (Born, Amann, Grunze, Post, & Schärer, 2014; Denicoff et al., 2000; Koenders, Nolen, Giltay, Hoencamp, & Spijker, 2015); or Patient Mood Chart (PMC) (Parker, Tully, Olley, & Barnes, 2007) which allows the reporting of (hypo)mania and depression as an overall mood state (rather than reporting on individual symptoms), typically over several weeks or months to detect and monitor changes. A charted mood log however would not detect the subtle variations in day-to-day mood over a shorter period, or provide data on specific, individual mood symptom severity (symptoms contributing to (hypo)mania or depression).

To date, the only published self-report daily mood monitoring tool specifically for BD mood symptoms which measures individual symptom variability is the Mood Zoom (MZ) mobile application (Tsanas et al., 2016) which measures symptom severity across six items *(anxious, elated, sad, angry, irritable, energetic)* on a seven point Likert scale (1-7). MZ was developed from established, standardised questionnaires to measure key features of mood daily rather than weekly (7-day recall) using only one rather than multiple questionnaires, and asks participants to rate symptoms to the extent they describe their current mood from 'not at all' (1) to 'very much' (7). Overall the MZ items showed acceptable concurrent validity against their related questionnaires (Tsanas et al., 2016), for example: *'sad'* and depression (Quick Inventory of Depressive Symptoms; Rush et al., 2003) r=0.69 (p<0.0001) ; *'elation'* and (hypo)mania (Altman Self-Rating Mania Scale; Altman et al., 1997) r=0.26 (p<0.0001); and *'anxiety'* with generalised anxiety (Generalised Anxiety Disorder Scale; Spitzer, Kroenke, Williams, & Löwe, 2006) r=0.77 (p<0.0001). Levels of agreement however were not reported in Tsanas et. al. (2016). The daily mood log for the requirements of this PhD was a paper adaption of the daily MZ mobile application (Tsanas et al., 2016) which took approximately 3mins to complete when tested.

Weekly mood: (hypo)mania

The Altman Self Rating Mania Scale (ASRM) (Altman et al., 1997) (five items) determined the presence and severity of (hypo)mania symptoms using a 'last 7-days' format where required within this PhD research. Altman et al. (1997) reported the ASRM as having good internal consistency (α=0.65-0.79) and concurrent validity with another commonly used tool, the Young Mania Rating Scale (Young *et al.*, 1978)) (r=0.72). Each ASRM item covers five domains used to diagnose

(hypo)mania according to DSM-IV (APA, 1994) (happiness, confidence, sleep, talking, activity) and are scored on a scale of 0-4. Furthermore, the participant group used as a sampling frame for this PhD were already familiar with the use of the ASRM, which was an additional, practical reason for selection (more details in participant recruitment section, page 91). The ASRM took approximately 5mins to complete when tested (see Appendix C).

Weekly mood: depression

The Quick Inventory of Depressive Symptoms (QIDS) (Rush et al., 2003), (16-items) determined the presence and severity of depressive symptoms in an exploration of device measured PA, SB and self-reported mood symptoms which used the ActivPAL3 to measure PA and SB. The questionnaire covers nine domains used to diagnose depression according to DSM-IV (APA, 1994) (sleep, sadness, weight change, decision making, view of self, suicidal thoughts, general interest, energy and psychomotor). Each QIDS item is scored on a scale of 0-3. Rush et al. (2003) reported the QIDS as having excellent internal consistency (α=0.86) and high concurrent validity against the 30-item Inventory of Depressive Symptomology (IDS; Rush *et al.*, (1986)) (r=0.96), as well as with the 24-item Hamilton Rating Scale for Depression (HAM-D; Hamilton, (1960)) (r=0.86). The QIDS is a widely used 7-day recall self-report tool (Toups et al., 2017; Tsanas et al., 2016), however it is a shorter, less burdensome questionnaire than the HAM-D or IDS. Furthermore, as with the ASRM, the participant group used as a sampling frame for this PhD were already familiar with the use of the QIDS, which was an additional, practical reason for selection (more details in participant recruitment section, page 91). The QIDS took approximately 5mins to complete when tested (see Appendix D).

The Beck Depression Inventory (BDI-21) (21-items) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) is also a well-established and commonly used self-report depression tool, and has been used extensively in previous research which has explored PA in mental health populations (Chum et al., 2017; De Mello et al., 2013; Parker et al., 2016; Vancampfort et al., 2015a). The BDI-21 was used to determine the presence and severity of depressive symptoms in a large-scale exploration of relationships between PA, SB and mood symptoms in this PhD. The BDI-21 was used instead of the QIDS for this large-scale exploration due to recruitment considerations when trying to collect data on PA, SB and mood in a large sample of people with BD. The best way to collect data from a large sample, was to work with an existing, well established research network, who currently use the BDI-21 in a bi-annual mailshot which is sent to participants as their measure of current depressive symptoms. To reduce the participant burden of completing more than one self-report measure of depression, the BDI-21 was selected for use in this PhD when exploring relationships between PA, SB and mood in a large sample (more details in participant recruitment section, page 91). The BDI-21 took approximately 5mins to complete when tested (see Appendix E).

3.5 Method outline

Using the qualitative and quantitative methods outlined above, three individual studies (see Table 3.1 below), addressed the previously identified limitations and gaps within the literature by incorporating multiple perspectives, known as mixing methods through 'triangulation' (Mason, 2006). Each study investigated a component of the research question, combined using an integrative logic (Mason, 2006) to demonstrate how various explorations of the research relate to each other (see figure 3.1 below).

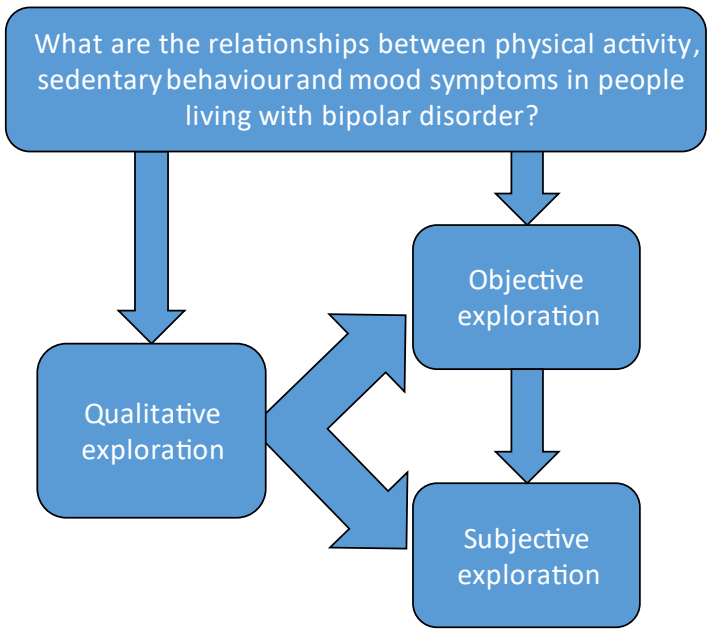


Figure 3.1 Study integration through mixed methods design

Table 3.1 Method outline of the three studies in this PhD thesis

Study	Aim	Design & Method	Purpose
Study one: Perceived relationships between PA, SB and mood in BD	1. To explore the perceived relationships between all forms of PA, SB, and mood by reflecting on the views and personal experiences of people living with BD.	*Qualitative:* • Semi-structured interviews • Analysed using a thematic analysis.	• Explore perceptions of relationships between PA, SB & mood. • Provide real life examples of relationships between PA, SB & mood.
Study two: Device measured relationships between PA, SB and BD mood symptoms	1. To explore the relationships between device measured PA, SB and self-reported daily and weekly mood symptoms in people living with BD. 2. To explore the validity of the Marshall Sitting Questionnaire (MSQ) (Marshall et al. 2010) for use as a self-report SB tool in people living with BD.	*Quantitative:* • Daily and weekly measurements of PA and SB over a 7-day period using an ActivPAL3. • Daily (Mood Zoom) and weekly (QIDS & ASRM) recording of mood symptoms using self-report questionnaires over a 7-day period • Compare device-based measurement of SB from an ActivPAL3 to sitting time of a self-report questionnaire (MSQ)	• Explore relationship between 'gold standard' measurements of PA and SB (ActivPAL3) with self-report daily (Mood Zoom) and weekly (QIDS & ASRM) BD mood symptoms. • Explore validity of the MSQ to assess SB time in BD by comparing to a device-based measurement of SB (ActivPAL3).
Study three: Subjectively measured relationships between PA, SB, and BD mood symptoms	1. To explore the relationships between subjectively measured, self-reported PA, SB and BD mood symptoms in a large sample of people living with BD.	*Quantitative:* • Distribution of self-report 7-day recall PA, SB, and depression (BDI-21) and (hypo)mania (ASRM) questionnaires.	• Capture PA and SB levels of a cross-section of UK BD population. • Explore nature and strength, of any relationships between PA, SB, and BD mood symptoms.

3.6 Participant recruitment

3.6.1 The Bipolar Disorder Research Network

The Bipolar Disorder Research Network (BDRN; bdrn.org) is a collaborative research network led by the University of Worcester and Cardiff University. BDRN has recruited the largest individual sample of research participants with BD and related mood disorders in the world. Currently, there are over 7,500 registered BDRN participants across the UK. Although BDRN investigate BD and related mood disorders, this PhD research will only explore relationships between PA, SB, and mood symptoms in people with BD type I (BDI) or BD type II (BDII). As this research is primarily focused on the mood symptoms specifically associated with BD, including less common sub-types of BD and related mood disorders (e.g. schizoaffective disorder and unspecified BD and related disorders) would provide mixed samples of participants, and findings which will be difficult to transfer within the BD population.

BDRN are primarily interested in identifying the environmental and genetic factors that may contribute to the aetiology and illness course of BD, and collect data on a range of psychological, biological and social variables: such as genetics; personality traits; social variables such as adverse life events, and mental and physical health. Participants can be recruited systematically by clinical studies' officers or research collaborators from the National Health Service (NHS) Trusts/ Health Boards where ethical approval has been obtained by the Health Research Authority (HRA) and authorisation from the local Research and Development department to recruit from these locations. Non-systematically recruited participants are recruited through national support groups such as Bipolar UK (bipolaruk.org) using information leaflets;

via media advertisements; or online via the BDRN website (bdrn.org). Interested participants receive a participant information sheet.

BDRN have the following inclusion criteria to participate in their research: to be aged eighteen or over and able to provide written informed consent. Participants are also screened for eligibility using generic questions such as: ‘have you ever received a diagnosis of BD from a healthcare professional?’ and, ‘have you ever experienced severely elevated mood that lasted more than four days?’ to determine if they are likely to meet lifetime DSM-IV criteria for having ever had a (hypo)manic episode. Exclusion criteria applied to people who had only experienced affective illness secondary to the misuse of alcohol or substance misuse, or those with a cognitive impairment affecting their ability to engage in a diagnostic interview or complete other measures such as questionnaires.

Eligible participants then take part in a semi-structured interview using a shortened version of the Schedule for Clinical Assessment for Neuropsychiatry (SCAN) (World Health Organisation: Wing et al. 1990). The purpose of using SCAN is to assess lifetime psychiatric history, and to identify key illness features, such as the onset of impairing affective illness, number of episodes of affective illness, duration and severity of symptoms, as well as demographic data. SCAN is a widely used assessment tool which requires extensive training to administer, therefore enhancing inter-rater reliability. However, limitations are that it is time-consuming, and relies on lifetime self-reports of the participant, which can elicit recall bias. The SCAN interview is supplemented by psychiatric case notes where available to provide contemporaneous information to support diagnosis and clinical history data. All clinical data available is compared to the DSM-IV (APA, 1994) criteria to gain a best estimate main lifetime diagnosis of BD. If there was any doubt about the diagnosis or

ratings, at least two members of the BDRN research team, each blind to the others' ratings, produced diagnostic and clinical ratings and a consensus was reached. Inter-rater reliability was high. Mean Kappa statistics were 0.85 for DSM-IV diagnosis and ranged between 0.81 and 0.99 for key clinical, categorical variables. Mean intra-class correlation coefficients were between 0.91 and 0.97 for key clinical continuous variables. Team members involved in the interview, rating and diagnostic procedures were all trained research psychologists or psychiatrists.

Participants who consent to ongoing contact with BDRN receive an annual newsletter informing them of BDRN research updates and to advertise specific research projects as well as subsequent questionnaire mailshots (which include the ASRM and BDI-21 self-report tools) which are used to further explore BD in relation to other variables, for example physical health co-morbidities. Recent feedback from BDRN participants has highlighted that PA is something participants think is important to investigate in future research.

BDRN are therefore a suitable and valuable recruitment resource and sampling frame for this PhD research, as they have a large UK participant sample of people with a best estimate main lifetime diagnosis of BDI and BDII who have consented to further contact in relation to BDRN research. BDRN also have a relevant, and detailed dataset that is regularly updated to draw upon for this PhD research. This includes a subset of approximately 1055 participants who are actively engaged with on-going BDRN research projects (who regularly complete the QIDS and ASRM self-report tools). This group of participants were therefore the first to be contacted about aspects of this PhD which required more frequent participant contact (such as study one and two).

3.6.2 Recruitment considerations

Figure 3.2 below outlines the search criteria and filtering process used to identify potential participants for this PhD research from a BDRN participant database. A BDRN staff member carried out this search according to the inclusion criteria: participants who had a best-estimate main lifetime diagnosis of BDI or BDII and had previously consented to be contacted again.

Study one and study two both required participants to live within reasonable travelling distance of the University of Worcester, so that the researcher could interview them in person if possible to gain rapport, and/or support them with applying the ActivPAL3 activity monitor if required. These participants were recruited in stages, though waves of recruitment (see Appendix F) due to their geographical spread and distance from the University of Worcester, and to avoid the researcher being overwhelmed with participant interest, as studies one and two required direct and frequent contact with participants to arrange participation and home visits. Only participants who had provided BDRN with an email address were contacted to take part in studies one and two to ensure information regarding what participation involves, and confirming interview/ activity monitor delivery slots were provided in a timely manner prior to participating in either study, and to provide a quick response to any participant queries.

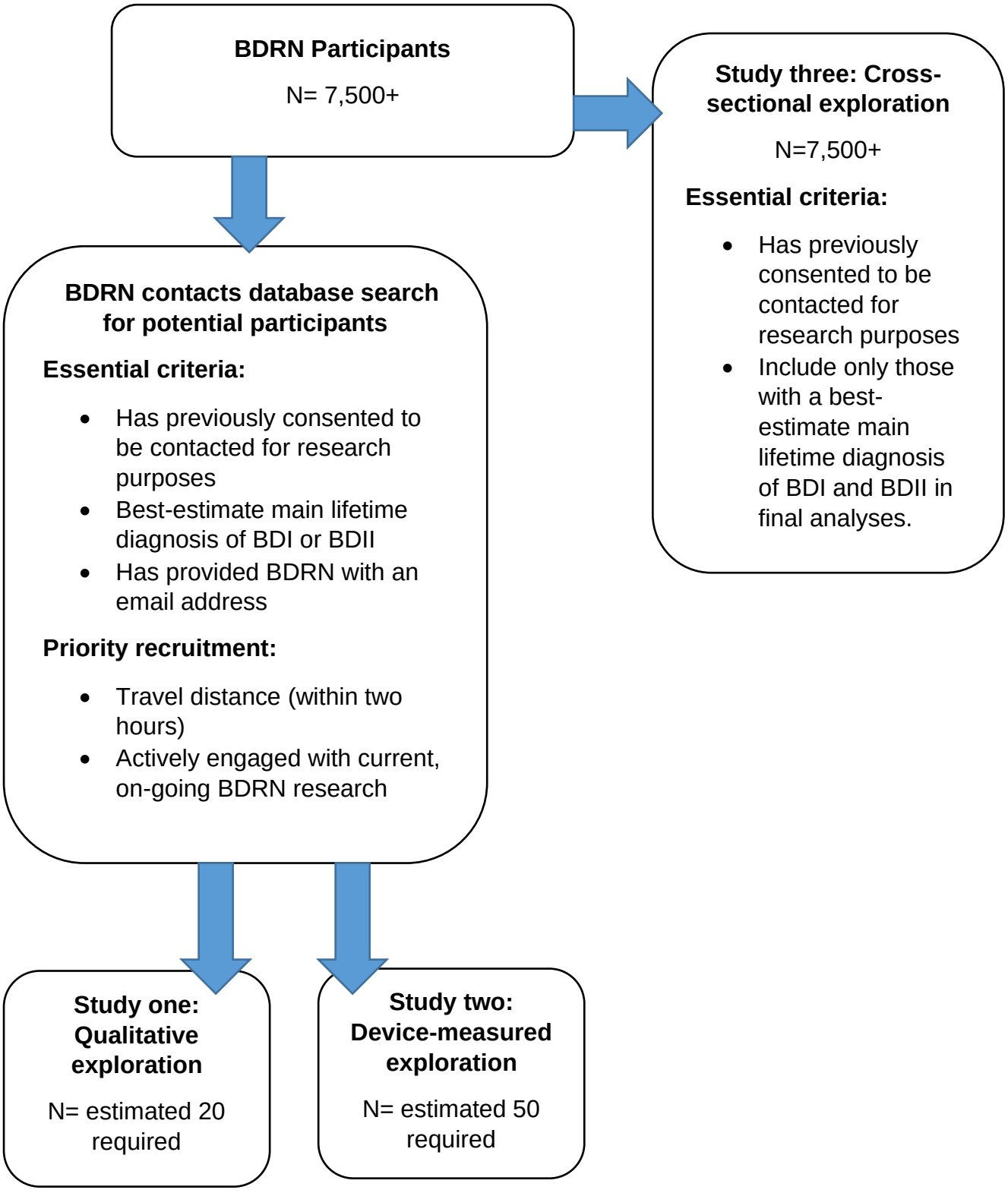


Figure 3.2 Participant recruitment flow chart

3.7 Ethical considerations

All participants were fully informed of the requirements of the research and the ability to opt out at any time without affecting their BDRN membership.

3.7.1 Ethical approval

BDRN have HRA ethical approval to recruit participants to their on-going research (MREC 97-7-01). However, additional HRA approval was required in the form of a substantial amendment for the bi-annual questionnaire mailshots (including study three of this PhD) and any additional research projects, such as study one, and two of this PhD. Study one and Study two received ethical approval on 20-12-17 (amendment number: SA10). The questionnaires for study three received ethical approval on 23-10-18 (amendment number: SA11).

3.7.2 Data protection & storage

Each BDRN participant has a unique study ID which their research data is stored under to protect any personal information that could make them identifiable. No personal identifiers were publicised in this research. The key that links the study ID to participants' personal identifiers is stored separately to the research data by BDRN.

Electronic data collected from participants (both by BDRN and specifically for this PhD) is password protected and stored on the University of Worcester's secure server. Paper-based data are stored in a locked filing cabinet under participant study IDs, in a locked room at the University of Worcester with controlled, restricted access. The above storage procedures are in line with the conditions of the HRA approval and GDPR guidance at the time of completing this PhD research.

3.7.3 Researcher safety

Throughout all aspects of data collection which required the researcher to visit participants at home, a BDRN safety policy which had been adapted specifically for this research was implemented to protect the safety of the researcher. This included guidance on logging on and off with another member of the BDRN team, and an escalation procedure it the researcher failed to do this. The policy also outlined safety concerns to consider when arranging home visits such as the time of day, parking, and carrying any valuable items such as a laptop. A mobile phone specifically for use during this PhD research was used to make telephone contact with participants to protect the researcher's confidentiality.

3.7.4 Participant safety

Participants who responded to say they were interested in taking part in study one and/or study two were screened to establish current mood state before arranging participation. This was to ensure that the participant felt well enough at the time of participation, as it would have been unethical to interview or ask a participant who has a severe episodic illness to wear an ActivPAL3 if they were experiencing an episode of illness or severe impairment at the time. Study three could be completed at the participants' convenience and did not require a visit from the researcher and so did not require a screening process.

Screening was conducted via telephone within two weeks of the arranged participation date and included questions such as:

1. How are you feeling in your mood at the moment?

2. Have you had any inpatient or intensive home treatment for BD in the last month?

If there were any concerns through conversation with the participant that it was not appropriate for them to participate at that time (for example they had had recent treatment for a mood episode), the researcher suggested that arranging the visit was postponed for a minimum of two weeks to allow time for recovery. If there were no concerns, a suitable time for either a home-visit or telephone interview was arranged for study one, and delivery of the activity monitoring equipment arranged for study two. If the arranged date for participation was over two weeks in advance, the researcher would make contact with the participant again to ask about their mood prior to the participant taking part in either study. If, despite the screening process being carried out, a participant presented as unwell during participation in either study, the researcher would have offered to cancel/ delay participation and make an informed decision to cancel if necessary, although this was not required at any time.

4 Chapter Four: The perceived relationships between physical activity, sedentary behaviour & mood, in people living with bipolar disorder

4.1 Introduction

This chapter is a presentation of the qualitative study which explored relationships between physical activity (PA), sedentary behaviour (SB) and mood, from the perspective of those living with bipolar disorder (BD).

Previous qualitative research exploring experiences of PA and mood in those living with BD was limited to experiences of exercise (Bauer et al., 2018; Glowacki, et al., 2017; Mason & Holt, 2012; Pickett et al., 2017; Searle et al., 2012, 2014; Wright et al., 2012). Furthermore, there was no published research at all which had aimed to explore perceived relationships between SB and mood specifically in people living with BD. Therefore, the aim of this qualitative study was to explore perceived relationships between PA, SB and mood in people with BD.

Experiences of PA and SB engagement may vary between participants, and participants may have different experiences of PA and SB engagement during their lifetime, and for various reasons, for example injury, sickness, or a change in employment or routine. People living with BD may, or may not, have perceived these experiences of PA and/or SB to be related to a change in their mood. In this study it was therefore important to try to identify which experiences of PA and/or SB identified by participants were also perceived to be related to changes to their mood, and to interpret the relevance of this. It was also important to consider any factors identified by participants as being related to PA and/or SB, to aid understanding of these perceived relationships in day-to-day life.

Thematic analysis allows for focus on the interpretation of participant experiences to explore patterns and differences through the creation and presentation of data themes (see Chapter three, page 76 for details on why thematic analysis was chosen for the qualitative aspect of this PhD). Braun and Clarke's (2006) six-step method of thematic analysis was used in this study as a means of constructing themes which help to explain the observed patterns and differences in the perceived relationships between PA, SB and mood within data from semi-structured participant interviews. Srivastava and Hopwood's (2009) framework for qualitative analysis supported the process of carrying out a thematic analysis by prompting consideration of three key questions: 1. What is the data telling us? 2. What is it we want to know? 3. What is the relationship between what the data is telling us, and what we want to know? allowing the analysis to stay focused on the study aim, and supporting the more deductive aspects of this study where distinctions between what the participant was communicating, and where and how this related to the study aim were required. This focus was important as semi-structured interviews can be detailed, including discussion of lots of material which may not be relevant to the study aim. Given that BD is a complex illness that can impact on many aspects of life, it was anticipated that participants might also want to discuss other aspects of their experiences of living with BD, other than PA and SB.

A further purpose for carrying out a qualitative exploration was to aid the understanding and interpretation of relationships observed between PA, SB and mood from device-based and subjective measurements of these relationships presented later in the thesis. This was important as lifestyle and behaviour change programmes currently attempting to increase PA and reduce SB in people living with

BD may benefit from an understanding of how experiences of mood in BD may relate to PA and/or SB engagement.

The qualitative study was carried out first due to difficulties managing researcher positionality and transparency that may have arose from interviewing participants about their perceptions of PA, SB and mood after already exploring this statistically (e.g. interpreting the data to 'fit' a conclusion already made following quantitative methods). Furthermore, carrying out data collection for this study prior to undertaking any data collection for the other studies in this PhD provided an early insight into potential factors to consider when examining the relationship between PA, SB and mood using quantitative methods, and also avoided participant bias from those who participated in other studies in this PhD. The participants' perceptions and experiences of relationships between PA, SB and mood presented in this chapter are therefore not influenced by their experiences of participating in the other studies. This was also important given the sequential approach taken to the studies within this PhD (see pages 73-74, Chapter three).

4.2 Aim & objectives

Aim: To explore the perceived relationships between all forms of PA, SB and mood in BD by interpreting the views and personal experiences of people living with BD.

Objective 1: To qualitatively explore relationships between all forms of PA, SB and mood in BD by conducting semi-structured participant interviews.

Objective 2: To identify and report on any patterns and differences between participants' experiences and perceptions of the relationships between PA, SB and mood in BD to provide the 'real life' component to the PhD as a whole.

Objective 3: To construct and report themes which explain the patterns and differences in the perceived relationships between PA, SB and mood in BD.

4.3 Method

4.3.1 Interview topic guide

A semi-structured interview topic guide was developed specifically for this study to address topic areas largely unexplored in previous literature. These included: experiences of general PA other than specific exercise; and experiences of high mood in relation to SB. Through discussion with PhD supervisors the topic guide was condensed down to five key but broad open-ended questions (see Figure 4.1 & 4.2 below). As there have been few published qualitative works in this area, it was important to consider Srivastava and Hopwood's (2009) second question in their framework of 'what is it we want to know' and not to assume too much prior knowledge on behalf of participants. Brief definitions of 'exercise' (e.g. 'by exercise I mean something you do to keep fit and healthy') and 'PA' (e.g. by 'PA I mean day-to-day movement and activities that require you to be on your feet) were provided to try and distinguish experiences of exercise and mood from PA and mood. A number of potential interview prompts were included in the topic guide to support the participant with providing more detail if their responses were brief, to delve deeper and get underneath the description in order to interpret meaning, or to guide them back on topic if interviewee responses moved away from PA, SB or mood (see Figure 4.1 & 4.2). The interview topic guide was presented to BDRN research staff who have experience interviewing people with BD for additional expert feedback, and was then used in role-play interviews with the research supervisors and two BDRN research staff before participant recruitment began.

Interview Topic Guide

Living with Bipolar Disorder

Key topic:
Personal awareness of changes in mood and mood symptoms

Key question:
Please tell me about your mood symptoms generally, what symptoms you experience and how you identify or manage any mood symptoms.

Prompts:
Gradual, over time, immediate, sudden, reflective awareness/ coping mechanisms, strategies, general support/ **(hypo)mania, depression, mixed mood**/ severity, impairment, early symptoms, later symptoms, indicators, triggers, predictors.

Specific Exercise

Key topic:
Engagement with specific exercise/ sports.

Key question:
Do you engage with any specific exercises or sports? Please tell me about these.

Prompts:
Type of exercise, / solo, team, friend/ why do exercise, important or not/ how often, duration, changes, engagement, fluctuating, constant, patterns/ time of day.

Physical Activity/ Inactivity and Sedentary Behaviour

Key topic:
General day-to day activity levels and changes in activity (explain definition of general)

Key question:
Are there times you feel that you are more active or less active than what is normal/typical for you *(when you feel well/ asymptomatic)?*

Prompts:
Examples- housework, walking to shops, work/ sitting time/ activity monitoring/ barriers, facilitators, motivators/ other influences or impacts on PA/ time of day, time of year, schedule, work, leisure/social, domestic, travel, friends/family.

Figure 4.1 Interview topic guide page one

Relationships Between Physical Activity/Inactivity and Mood

Key topic:
Identifying links between physical activity/ inactivity and mood.

Key question:
Do you think there is a link or connection between how active you are, be it exercise or just moving around more or less than usual, and your mood?

Key prompts:
Nature of relationship, link to mood, relevant/ influences, changes- what noticed first / strategies, management, awareness/ sitting/ PA/ changes in mood, depression, (hypo)mania, mixed mood.

Interview Close

Key topic:
Interview close – any additional information

Key question(s):
I would like to know if there is anything that you thought I was going to ask you regarding physical activity that I haven't asked today? Please feel free to talk to be about this now.

Key prompts:
Addition to any previous answers/ influences of interview topic on answers/ literature (double-edged sword)

Figure 4.2 Interview topic guide page two

4.3.2 Participants

4.3.2.1 Reviewing sample size

Previous qualitative research conducted to explore similar topic areas with similar participant groups have reported varying sample sizes. Pickett et al., (2017) interviewed 26 participants with depression on how and why PA may benefit depression, a similar number to Wright et al., (2012) who recruited 25 individuals with BD to take part in an interview on experiences of exercise. A study by Bauer et al., (2018) included a focus group and follow up interviews of 10 participants with BD on their experiences of a lifestyle intervention aimed at changing unhealthy behaviours and improving nutrition and PA in people with BD. Searle et al., (2012) first recruited 12 GP participants to talk about their views on PA as a treatment for depression, later recruiting 19 patient participants to be interviewed on their experiences of PA for depression in primary care, with 12 being re-interviewed 8-months later (Searle et al., 2014). The above published research reports a broad range in sample size from 10 to 26 participants, with those specifically investigating BD ranging from 10 to 25 participants, however only Pickett et al. (2017) refer to data saturation being achieved (through convenience sampling and then purposive sampling to target participant characteristics considered relevant to the study aim). The other studies did not publish their decisions around concluding data collection or the demographic characteristics of the sample in relation to the findings, and so it is difficult to determine whether data collection ended due to considering the study aim as having been met; because of recruitment challenges such as obtaining heterogeneity (if relevant), or for other reasons. This is particularly unclear for the studies who report lower sample sizes. However, all studies referenced here adopted different theoretical frameworks which may have influenced sample size

and decision making in regard to recruitment and the decision to end data collection. For example, Wright et al. (2012) used a combination of advertisement and contacting people who had expressed a previous interest in being interviewed for recruitment and followed an Interpretative Phenomenological Analysis (IPA) where the aim is to provide rich, full accounts of experience rather than aiming to achieve saturation, (Smith, Flowers & Larkin, 2009). However, they provide a considerably large sample size compared to other IPA studies, potentially due to wide successful advertisement using their chosen method of recruitment. Bauer et al. (2018) reported originally aiming to complete three focus groups which would normally produce a large sample size, however they struggled with low recruitment and attendance rates and only completed one focus group.

In relation to the current study, it was acknowledged that recruitment may be challenging due to the episodic nature of BD and that a requirement of the ethical approval (HRA) was not to interview a participant who may be considered unwell at the time of participation. With the above previous research and considerations and challenges in mind, approximately 20 participant interviews was considered a reasonable number to aim to recruit to meet the study aim, and that this would be reviewed using Malterud, Siersma, and Guassora (2016) concept of 'information power' once it was felt that enough interviews may have been completed to meet the study aim. Information power is a way to assess and review sample size in qualitative research against five categories: aim (narrow or broad?); specificity (dense or sparse?); theory (applied or none?); dialogue (strong or weak?); and analysis (case or cross-case?) which are outlined in Figure 4.3 below:

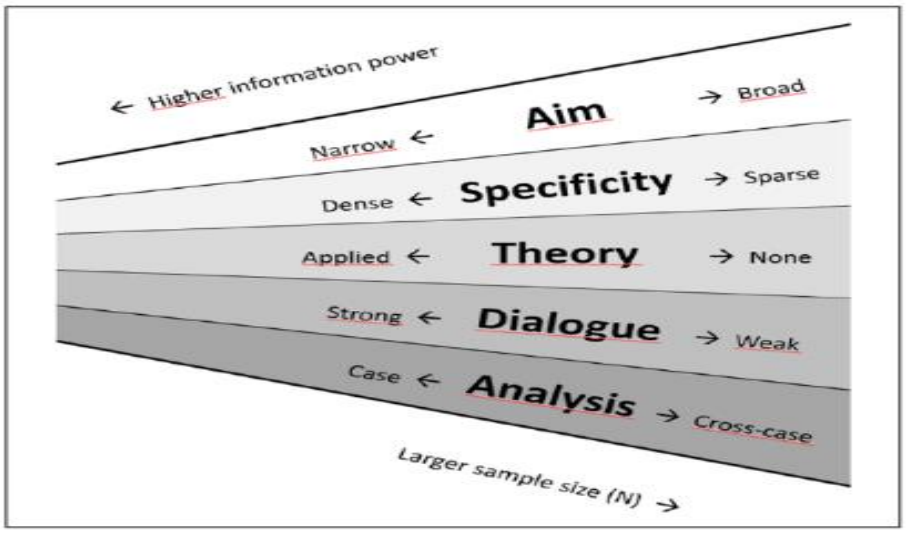


Figure 4.3 Scale on which to assess & review information power. Permission to reproduce obtained from SAGE publications March 2020

The concept proposes that the more information power a sample provides, the fewer participants that are required. Information power can be reviewed at any stage during interviewing to help the researcher decide when they have accumulated sufficient data to meet the study aim, and whether more participants are required.

Braun and Clarke, (2019b) question the notion of data saturation as being 'achieved' somehow in studies using thematic analysis, acknowledging instead that 'knowing' when to stop collecting data is in reality a subjective milestone embedded in data analysis which cannot necessarily be pre-determined. For this reason, Braun and Clarke, (2019b) also suggest information power as a more suitable alternative for reviewing sample size and data collection in studies using thematic analysis.

4.3.2.2 Inclusion & exclusion criteria

BDRN participants with BD type I (BDI) or BD type II (BDII) who lived within an hour's drive of the University of Worcester and who were actively engaged in BDRN research (see Appendix F) were the first invited to take part (N=37). No exclusion criteria were applied to open-up participation as widely as possible to encourage a heterogeneous sample of participants (i.e. males and females across various ages and with varying levels of PA/SB engagement) to explore any potential differences which may be important to explore further in studies two and three.

4.3.2.3 Study invitation

The study invitation was an email (Appendix G) inviting participants to take part in an interview exploring the relationships between PA/inactivity, SB, and mood in BD. The email asked interested participants to respond to the email with a contact telephone number. A reminder email was then sent two weeks later to participants who had not responded to the initial invitation. Thirty-seven BDRN participants received the study invitation email in late April 2018.

4.3.2.4 Recruitment process

Seventeen BDRN participants responded to say they would like to take part in the study (with no participants responding specifically to decline the research invitation). These participants were then contacted by the researcher via telephone to carry out the mood screening (see page 97), and to arrange a suitable time for either a home visit or a telephone interview. Participants then received an interview appointment confirmation email (see Appendix G).

Of the 17 participants, 15 were interviewed. One participant did not respond with a contact telephone number following email prompts, and one participant missed their arranged interview and did not respond when contacted to arrange another interview date. One participant reported during the mood screening phone call that they were unwell at the time, and so participation was postponed for three weeks and then another mood screening was carried out before arranging and conducting the interview.

4.3.3 Procedure

All interviews were completed between late April to mid-June 2018. During the interview, participants were asked the six key questions from the topic guide. As the interview topic guide was semi-structured, not all questions had to be asked if the participant was very forthcoming with detail in relation to the topic areas. The questions also did not need to be asked in a set order to allow the participant to speak freely without the interviewer interrupting the narrative and flow of thought, whilst gently steering conversation back on topic if required.

All participants agreed to be audio-recorded, and interviews were recorded using a dictaphone. The researcher made brief notes under each topic area on a copy of the topic guide during the interview which were reviewed by the researcher prior to each subsequent interview. As the interviews progressed, the researcher asked participants about the experiences described by other interviewees to see if these resonated with the participant currently being interviewed, for example when participants talked about experiences of exercise in relation to mood, the researcher might have asked: ‘some people I have interviewed have talked about exercise being helpful for mood regulation, do you have any experiences of this, or thoughts on

this?' The researcher kept personal notes and reflections on each interview in a note-book which was used to bullet point the researcher's perceived 'take home message' from each interview. This helped the researcher to process early reflections and any assumptions from each interview which were then reviewed during theme development (i.e. candidate themes). More in-depth detail on theme development and candidate themes is provided in Appendix I.

The interviews were challenging at times, and it was important to try and build rapport from the first contact (i.e. from the recruitment email, and when arranging the interview via telephone). This was achieved by offering choices where possible (such as a telephone call or home visit, the day or time of day of the interview), using clarifying questions to show interest, and demonstrating an understanding of BD without making assumptions about the participants own experience. Detail of the researcher's previous work experience in mental health and interview experience is documented in Appendix S to offer transparency of any prior assumptions of physical activity and mental health and highlight any potential bias. A particular challenge during the interviews was keeping on topic whilst also being mindful that participants had varied experiences of living with BD that they wanted to share. It was important to allow participants space to share these experiences and feel listened to. Ultimately, although the researcher would gently use prompts to try and keep the interview focused on the topic guide, priority was placed on the maintenance of rapport with participants first and foremost, demonstrated through the interest shown in what the participant was saying.

4.3.3.1 Information power

Following the 15 interviews, the concept of information power (Malterud, Siersma & Guassora, 2016) was used to re-evaluate sample size and recruitment. The average interview time was 40mins, and the interviews became shorter in duration as the process went on. The first interview was 80mins long, with the final interview lasting only 20mins. This indicated that the *'specificity'* of discussion was becoming more *'dense'* and focused as interviewing had reached a stage where the flow of conversation was not unearthing new areas to explore or prompt further. Also, the last few participants' responses highlighted patterns which were similar to that of previous participants interviews (*'analysis'* – *'cross-case'*) which would allow for the creation and reporting of themes to explore these patterns and any differences. Furthermore, the interview data showed great depth in regard to experiences of PA, SB and mood both singularly and in terms of the relationship between the variables, providing *'dense'* detail and requiring very little prompting from the interviewer (*'dialogue'* – *'strong'*). The study *'aim'* could be considered both *'narrow'* in regard to looking specifically at relationships, and specifically in people with BD, however *'broad'* in other areas, such as looking at all forms of PA, and not just specific exercise. Where earlier interviews focused on broader aspects of the study aim such as experiences of PA, as the interviews progressed the interviews became shorter and more focused towards the overall study aim of examining *relationships* between PA, SB and mood in BD. In terms of *'theory,'* although there was no established theory being used to guide the analysis (which would require a smaller sample size), previous research was highlighted in Chapter two identifying links between depression and PA and SB, and the interview topic guide had been designed to address the issue of there being no existing 'theory' of the relationships specifically

between PA, SB, and mood in BD. The 15 interviews provided information on perceived relationships that contributed towards theory and addressed gaps in the literature.

As the interviews progressed, there were clear similarities between experiences that demonstrated perceived relationships between PA, SB and mood in people living with BD. Therefore, following the analysis of the first 15 interviews, it was concluded that there was sufficient information power in each of the 5 areas to address the study aim without the need for further recruitment.

4.4 Data preparation & analysis

4.4.1 Transcription

Transcription was an on-going process from April to early September 2018. Initially the aim was to transcribe each interview verbatim before conducting the next to help with familiarisation of the data and to start the iterative, reflective process of qualitative research. However, given the availability of the participants, all interviews were completed within two months. This was to avoid participants losing interest whilst waiting to be interviewed after volunteering, as well as time constraints to tie this study in with other aspects of the PhD (see Chapter three, pages 73-74) as one of the purposes of completing this study first was to aid the interpretation of the results from device-based and subjective measurements of PA, SB, and mood. On three occasions more than one interview was carried out on the same day due to the geographical closeness of participants and their given availability. Where practically possible the notes made under the topic areas on the interview topic guide were reviewed prior to the next interview, and the interview recording was played back, however it was not feasible for all interviews to be listened to and transcribed prior to conducting the next. Once all of the interviews were completed, listened to, and transcribed, the printed interview transcripts were then read and checked for accuracy against the recording.

4.4.2 Thematic analysis

Braun and Clarke (2006)'s method does not encourage the use of member checking/validation (i.e., returning transcripts to participants for them to confirm their transcribed account and/or the researcher's interpretation of the data) as evidence of 'trustworthiness,' however acknowledges the active role the researcher has in creating themes and interpreting from the data, and that the rigour of thematic analysis is determined by following the systematic process, which can be replicated. Therefore, Braun and Clarke (2006) created a 15-point checklist (see Table 4.1 below) to assess the rigour of thematic analysis and encourage clarity on the reporting of how their 6-step process was carried out.

Table 4.1 Braun & Clarke's (2006) 15-point checklist of criteria for good thematic analysis

Process	Number	Criteria
Transcription	1	The data have been transcribed to an appropriate level of detail, and the transcripts have been checked against the tapes for 'accuracy'.
Coding	2	Each data item has been given equal attention in the coding process
	3	Themes have not been generated from a few vivid examples (an anecdotal approach), but instead the coding process has been thorough, inclusive and comprehensive.
	4	All relevant extracts for all each theme have been collated.
	5	Themes have been checked against each other and back to the original
	6	Themes are internally coherent, consistent, and distinctive
Analysis	7	Data have been analysed - interpreted, made sense of - rather than just paraphrased or described.
	8	Analysis and data match each other - the extracts illustrate the analytic claims.
	9	Analysis tells a convincing and well-organized story about the data and topic.
	10	A good balance between analytic narrative and illustrative extracts is provided.
Overall	11	Enough time has been allocated to complete all phases of the analysis adequately, without rushing a phase or giving it a once-over-lightly.
The written report	12	The assumptions about, and specific approach to, thematic analysis are clearly explicated.
	13	There is a good fit between what you claim you do, and what you show you have done - ie, described method and reported analysis are consistent.
	14	The language and concepts used in the report are consistent with the epistemological position of the analysis.
	15	The researcher is positioned as active in the research process; themes do not just 'emerge'.

This section therefore outlines the process of thematic analysis undertaken within this study, and provides examples of coding and theming to provide clarity on the processes of thematic analysis, and provide replicable steps for this study.

Step 1: Familiarisation of the data

Step 1 began during the data collection phase with the making and reviewing of initial notes taken during the interviews and listening back to the recordings regularly to become familiar with the data following transcription. The transcripts were then lightly annotated with initial thoughts that started to describe the data, e.g. ‘importance of routine’ and ‘medication having an impact’. The transcripts were then subjected to a deductive process of data selection whereby data relating to key topics from the interview topic guide were identified in the text and hand colour coded, (see Appendix H). Question one of Srivastava and Hopwood's (2009) framework for qualitative analysis which prompts qualitative researchers to ask ‘what is the data telling us?’ was particularly relevant here as the data was showing a complexity, and at times difficulty, for participants to focus on their experiences of PA and SB of BD.

The process of colour-coding helped with the familiarisation of the data by reading the interview in full once again and taking the time to consider how the data related to the study aim. This was particularly important given that the interviews were conducted in a relatively short time frame, and colour-coding the data ensured that familiarisation of the data was not rushed or skipped (see Table 4.1).

Step 2: Generating initial codes

Each transcript was subjected to three further stages of coding which were carried out by hand by the researcher:

- Open coding within the coloured sections to identify data and quotes of potential interest which revealed something relating to the research question. This stage was an opportunity to read the transcript again, and start applying general, initial codes to sections of data to allow the researcher to gain a sense of the spread of these early codes throughout all 15 transcripts. These codes were therefore predominately semantic at this stage and were made up of words used by the participant such as 'walking for transport' and 'bad weather a barrier to PA' to begin the interpretative process by developing an understanding of what the participant was trying to communicate during their interview.

- Line-by-line coding within the coloured sections was then applied, which allowed the researcher to continue the interpretative process using latent codes which captured more in-depth and complex thoughts and ideas by systematically going through the transcripts line by line. For example, one participant described the relationship between SB and depression as a *'self-feeding monster.'* This metaphor helped to describe this participant's perception that SB makes depression worse, and depression leads to more SB, as well as demonstrating the negative perception of this relationship being a 'monster.' It was helpful to consider this idea in other participants

transcripts who were describing the same relationship, but with different metaphors, for example *'it goes in a circle.'*

- The third stage was open coding *out with* the coloured sections, to ensure all potentially relevant information had been captured with a unique code. This final stage of coding was important to identify any data that may otherwise have been overlooked after reflecting on what had been identified in the earlier stages of coding within the coloured sections, i.e. had not been initially considered as important or relevant due to not clearly relating to the study aim. Coding examples are provided in Table 4.2 below.

Table 4.2 Examples of coding

Transcript Information	**Data**	**Code**
Transcript 2 (Jane) Telephone page 2 lines 25-47	*''I will do a lot of exercise and not even think twice about the impact that is going to have on my body later. Urm, and even when I'm in a great amount of pain I can't stop doing all the things that I am doing.''*	Pushing past physical limits Not being able to stop
Transcript 5 (Sarah) Home visit page 10 lines 220-222	*''I think if I was depressed it would be difficult. Based on previous, how I've been previously yeah I don't think that would be urm, possible. Partly because of the energy levels but also because of the thought pattern change''*	Low mood a barrier to PA A lack of energy when low in mood

Step 3: Searching for themes

Early interpretations and observations of the data shaped the initial groupings of the coded data into themes. These observations were made by printing and cutting up a list of all of the codes and grouping these into themes that could help describe and explain the data in terms of Srivastava & Hopwood's (2009) key questions. This process comprised of grouping and regrouping the codes under candidate theme names and considering those that did not fall into any suggested theme titles, and those that fit under more than one theme title, as a reflection of the specificity of the theme name. This was a challenging process due to the aim to explore relationships between constructs, rather than independent experiences of these constructs, which meant there was a high level of connectedness between codes, and the theme names. Braun and Clarke (2006) recommend making this process evident, and to reflect on the choices made here as part of the iterative process of analysis. Supplementary information on early themes and how and why these changed during the analytic process are therefore provided in Appendix I.

Step 4: Reviewing themes

The next step involved reviewing the themes with research supervisors of this PhD by going back to the data and re-reading the interview transcripts to determine whether the suggested theme names appeared to portray the concepts and ideas that had been captured with the applied codes. See Appendix I for more details on how this step-lead to the creation of the overarching theme, main theme, and sub-themes.

Step 5: Defining and naming themes

The theme reviews resulted in the following theme names being created:

Overarching theme: *'Trying to maintain balance'*

Main themes: *'Changing PA and SB levels' / 'Impact of PA and SB' / 'PA and SB changes as an early warning sign'*

First sub-themes*: 'Negative impact' / 'Positive impact' / 'Decreasing PA' / 'Decreasing SB'/ 'Increasing PA' / 'Increasing SB'*

Second sub-themes*: 'Determinants of volition' / 'Internal and external struggle' / 'Medication: A gatekeeper to activity' / 'Managing the unexpected'*

The theme groupings were designed to represent the areas of distinctiveness identified within the data, but also the connectedness of each main theme and its multiple sub themes. The theme groups create a path that can be followed to identify a particular finding. For example, the over-arching theme of 'trying to maintain balance' can be discussed in terms of 'the impact of PA or SB', being either 'positive' or 'negative,' in relation to 'medication.'

Together, the theme groups form the building blocks to support the over-arching theme of 'trying to maintain balance.' The nature of exploring a relationship between complex, ever-changing constructs such as PA, SB and mood rather than one individual experience is the reason the themes are not completely distinct from one another and overlap in areas.

4.5 Findings

This section includes demographic information on the participants interviewed, and descriptions of the overarching theme and three main themes of this study, with reference to the multiple subthemes woven in throughout. All subthemes related to the overarching theme of ‘trying to maintain balance’ as well as the three main themes.

Thematic maps visually present the key subthemes and codes that make up each theme, supported in the text with quotes from participant interviews that explain the patterns and differences in perceived relationships between PA, SB, and mood from the perspectives of people living with BD.

4.5.1 Participant descriptive information

Table 4.3 and 4.4 below provide demographic information on the 15 participants who were interviewed. To maintain confidentiality, individual research diagnoses and age were removed from the individual demographics (Table 4.3) and are presented as summary figures in Table 4.4.

Table 4.3 Descriptive information for individual participants in study one

Transcript number	**Pseudonym**	**Interview recording time HH:MM**	**Interview type:** H: home visit T: telephone	**Gender** F: female M: male
1	Susan	01:19	H	F
2	Jane	00:48	T	F
3	Martyn	00:35	H	M
4	Joanne	00:43	H	F
5	Sarah	00:47	H	F
6	Hilary	00:37	H	F
7	Holly	00:40	T	F
8	Abbie	00:45	H	F
9	Eleanor	00:36	H	F
10	Rose	00:25	H	F
11	Richard	00:35	H	M
12	Carol	00:22	T	F
13	Ben	00:58	T	M
14	Callum	00:28	H	M
15	Catherine	00:21	H	F
		Totals:	H= 11 (73%) T=4 (27%)	F=11 (73%) M=4 (27%)

Table 4.3 shows that more female participants were interviewed than males. Most participants chose a home visit interview rather than telephone interview. Only 4 participants opted for a telephone interview due to work or other commitments limiting their availability for a home visit, however there was little difference in interview timings regardless of whether the interview was conducted via telephone or by home-visit. Table 4.3 also shows that overall the interviews had shortened in length as they progressed. Ben's interview was longer (58mins), however also contained the most data on personal experiences that did not relate to PA, SB or mood and therefore contribute to the study aim.

Table 4.4 Summary demographic information for study one participants

	DSM-IV Research Diagnosis		**Age**		
	BDI	**BDII**	**Range**	**Interquartile Ranges**	**Mean (Standard deviation)**
Total *(N = 15)*	12 (80%)	3 (20%)	31 – 72 (41.00)	*Median*: 57.00 (43.00, 66.00)	54.80 (±12.81)

Table 4.4 highlights that more participants had a diagnosis of BDI than BDII, and most participants were over 50 years of age. These figures are demographically characteristic of the BDRN's total sample (N=7500+) of which there are more females than males, and more participants who have a research diagnosis of BDI than BDII.

4.5.2 Themes

4.5.2.1 Overarching theme: Trying to maintain balance

The over-arching theme of ‘trying to maintain balance’ came from the observation that participants identified PA, SB, and mood as related through their described experiences, however there was no consensus across the transcripts of a right or wrong way to balance PA, SB, and mood, or that there was a ‘cause-effect’ relationship present. PA, SB, and mood appeared to also be related to the individual needs, routines, and previous experiences of the participant. For example, participants were all using different medications, reported different ‘triggers’ or warning signs for their changes in mood, and described different levels of engagement with PA and SB. Therefore, whilst the data as a whole can be described in terms of ‘trying to maintain balance’ the main themes discussed later outline the patterns/similarities as well as differences described by participants within this struggle for balance, to highlight the perceived complexity and individuality of this (see Figure 4.4 below).

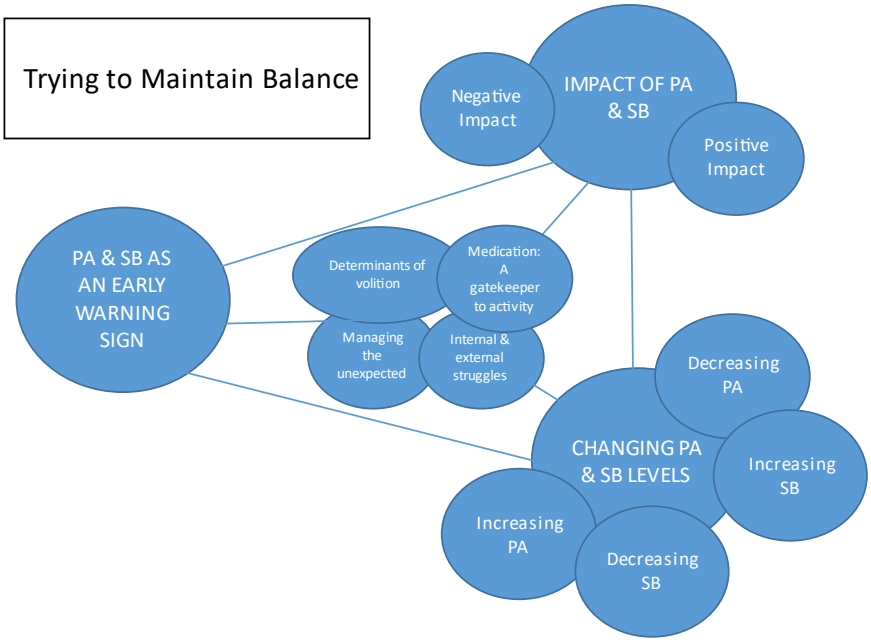


Figure 4.4 Theme connection & integration

All participants indicated that PA was helpful for mood regulation and for maintaining a sense of balance and wellbeing. However, participants also acknowledged the limitations of this, by identifying that 'knowing' that PA (particularly in the form of exercise), will help low mood but that actually engaging with this can be difficult, particularly when the low mood was considered severe.

Sarah: *"I'm always a bit wary of saying to people, that exercise helps my mood. Because…I can't bear that 'well why don't you just go out for a walk'…I've always known, you know, that it will help to a certain extent but also if you're seriously unwell it's not going to make the blindest bit of soddening difference either...you don't want to be too prescriptive and say well if you just went and did some exercise then you'd feel better."*

Abbie: *"if I was in depression to go right, I know exercise is going to make my mood better, that would take a lot for me to do."*

These examples suggest that for these participants there is an awareness of where increasing PA can have a positive impact on low mood, however this impact is lost if the low mood has amounted to a severe level of depression. This was a key finding

of this study, that PA may be helpful when managing mild to moderate changes in mood, but for severe mood changes PA may be a less helpful tool for mood regulation. This was evidenced throughout the themes and is an important consideration for the effectiveness of PA interventions in treating and managing BD episodes, and at which point an intervention stops being helpful. For example, when there is a perceived inability to control a situation or stop what is happening, an intervention may not be particularly helpful or even feasible. In addition, Sarah also voices a frustration at people misunderstanding her awareness that 'exercise' can be helpful for low mood, by acknowledging that if she is seriously unwell, it may not help her, but people may not be able to understand or appreciate this limitation of PA as a mood management tool.

A feeling of losing balance due to being 'out of control' when becoming unwell was also evident throughout the interviews:

Ben: *''It's hard to keep control of the situation. And there have been many periods when I've failed totally to keep control of the situation because of external influences.''*

Jane: [in reference to yoga] *''it's like my brain isn't telling me this is going to hurt you if you do this. My brain is just going 'you can do this, and then you can do this, and you can do this, and then you can do this…it's like that bit shuts down that says 'hey you need to take it easy now or else you're going to get into difficulties here…''*

Joanne: *''when I go high I tend to…sort of, start off bubbling and going very high very quickly…it's hard to catch things and sort of do anything about it…so very quickly I reach a point where I won't listen to reason and I tend to lose touch with reality…when I get really high that I decide that walking is the best form of transport and I just bump along at quite a pace and just sort of keep going''*

Rose: *''well my mother always said that she didn't like me being high because I'd be a bit out of control. She preferred it if I was depressed, I was more controllable if you see what I mean.''*

Richard: *''I'm not very good at addressing those things. I know what to do but I'm not very good at doing it because I just get carried away''''*

The above examples demonstrate a perceived difficulty to stop what is happening during an episode of illness and gives an impression of snowballing symptoms that are difficult to control. These examples also indicate that there is a level of awareness of being ‘off balance,’ however this awareness alone is not enough to regain control and balance. Jane and Joanne directly refer to engaging in PA and being aware that the loss of control was somehow related to PA> For example for Jane a perceived inability to stop physically pushing herself to do more, and for Joanne, a perceived inability to stop herself walking for long distances. This indicates that changes to PA engagement may be an early warning sign for a mood episode.

Figure 4.5 below provides a detailed view of the second stage subthemes, and some of the key codes that demonstrate the complexity of trying to balance PA, SB and mood in addition to external factors. These are the sub-themes that will be focused on in this section exploring the over-arching theme of trying to maintain balance, as these sub-themes were considered central to the relationship between PA, SB, and mood.

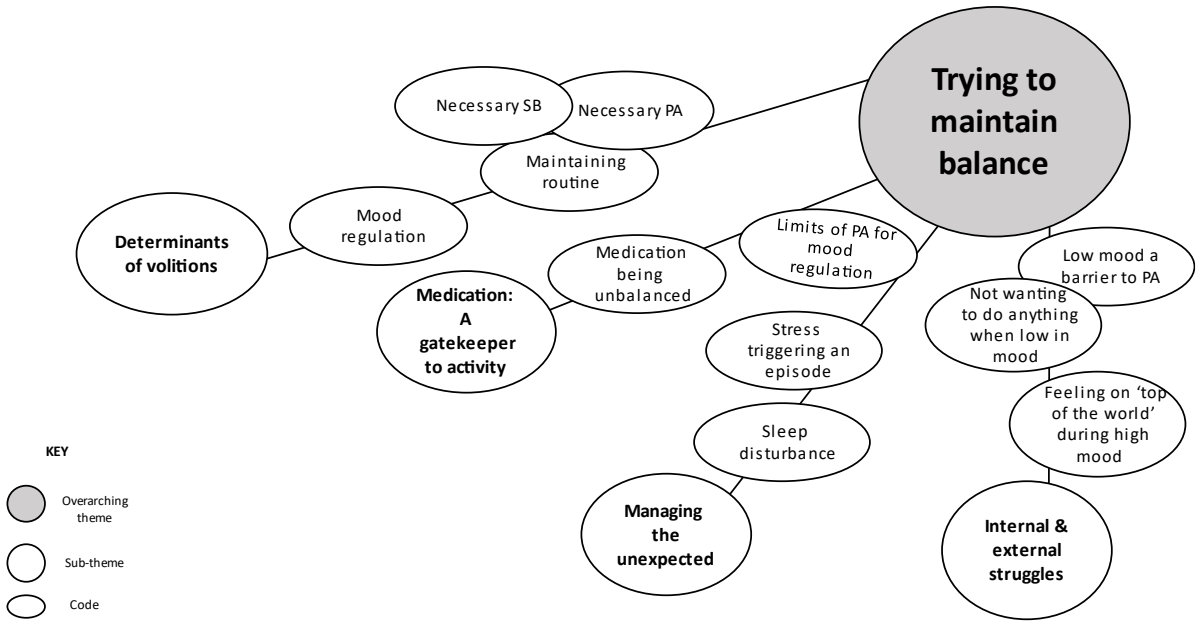


Figure 4.5 Thematic map 'trying to maintain balance'

Subtheme: Managing the unexpected

Difficulties relating to maintaining balance were identified as mood triggers, which were viewed as sudden changes in a participant's circumstances, situation, or ability to self-manage their symptoms. Participants talked about trying to manage or avoid known mood triggers, but that this was not always possible when the trigger is unexpected or sudden in onset. Sleep disturbance, or a lack of sleep, was the most commonly reported 'trigger' or contributor to a high mood episode as it was perceived to be one of the first noticed changes:

***Jane**: "I couldn't sleep, I had terrible trouble sleeping at night, and…I don't know, I did ask this once to the doctor on the ward and I think he agreed, it could have been that that could have triggered, the lack of sleep I mean, it just got to me in the end…I find lack of sleep is one of the major triggers… [interviewer: So lack of sleep, is that something you notice when you're high, or?] High. High I think that's what happens… because I'm doing more you see."*

Catherine: *"the last really big episode of psychosis prior to that I was waking quite early for a long period of time, like four in the morning. I wasn't exactly really active with it but I think the lack of sleep definitely triggers it a bit as well."*

Abbie: *"if I can keep my sleep on track, the mania tends to stay away… and not pacing the window "*

The above examples relating to a lack of sleep refer to increased PA in terms of 'pacing' and 'doing more,' but may also indicate an increase in SB during high mood due to being awake, but unable to sleep, as Catherine reports not sleeping and waking early, although not being really active.

Susan, Holly, Carol and Ben describe their sleep disturbance resulting in spending more time 'doing stuff' which related to an increase in PA:

Susan: *"if I go high it's just because I've woken up and I can't be bothered to stay in bed because I'll get up and do stuff "*

Holly: *"[Interviewer: So when you've had sleep disturbances do you stay in bed and try to force yourself to try and sleep or do you get up and move around. What happens?] So…in the last year or two I've been getting up a bit more…doing monotonous things like fold the clothes on the rack and stuff like that."*

Carol: *"[Interviewer: So when you come back from travelling would you say that your mood's quite low or is it…] No it's quite high, high yes…I'll need to do lots of washing, then I'll have to go out and mow the lawn, and it just goes on from there. Putting things away like the cases and towels and things and coming down at two o'clock in the morning and re-shuffling filing paper and stuff…it's just, a general, being unsettled."*

Ben: *"hypomania…yeah I feel on top of the world, take on a lot of projects and I don't need a lot of sleep"*

Some of the identified activities may have contributed to increased SB also. For example, Holly refers to 'recently getting up a bit more' implying that she used to not get up, and so would be sitting/lying awake in bed, indicating SB. Further, Carol and Ben describe activities most likely completed whilst engaging in SB, for example 're-shuffling filing paper' and 'taking in a lot of projects.'

This is indicative that part of the increasing PA and increasing or decreasing SB experienced alongside experiences of high mood is perceived to be related to more waking hours as a result of less sleep, and contributes to why PA and SB can be early warning signs for a mood episode. In the above examples, participants identified general PA that was productive, such as mowing the lawn and doing housework, more than specific exercise. This differs from other examples within this study where participants often used the term 'exercise' to describe all PA, not just structured activities that were carried out with the purpose of keeping fit despite the distinctions made by the researcher when following the interview topic guide, which is indicative that participants did not make the distinction between their PA behaviours.

In terms of sleep and SB, sleep was considered to also contribute to changing PA and SB levels for a low mood episode by either engaging with little to no PA due to over-sleeping, or not sleeping but not engaging with PA, and increasing time spent in SB:

Sarah: *"But yeah when I've had sort of…being low just having very little. Lots of sleeping, or no sleeping but not being able to move"*

Joanne: *"if I'm low I tend to…sleep the day away. I'll get up really really late."*

Catherine: *"with depressive symptoms it tends to be sleeping excessively…and I do sort of like, when I tend to get very depressed, lie down, not do too much"*

Richard: *"not wanting to go out. Jumping back into bed in the day, hiding away."*

Ben: *"During my worst times of depression, I've, I've stayed in bed most of the day with the curtains drawn."*

Callum*: "If I couldn't get up I would just sleep the day out. I can just stop, I wouldn't do nothing."*

Hilary: "*I got some stuff off the doctor to help me sleep and that made me even worse, that made me depressed…Because you sort of woke up feeling hungover and you sort of went into this sort of 'oh my God'…we used to call it a dog blanket day when I hide under the dog blanket."*

The above participants made reference to sleeping more, or at least trying to sleep more but not being able to when low in mood, which meant they were engaging in more SB, and less PA. Martyn was the only participant to make reference to sleeping less with low mood, experienced as part of mixed state symptoms, which he felt lead to an increase in PA:

Martyn: *"So low. So so low, I thought I was gonna die. I really really did. And I'd, walk at night and, wander round in the dark and people had to come out and find me and it was all, silly things…but I'm always, I can't sit still...I can't just sit and do anything I've gotta do something I'm active all the time...I could not just be, sit here and do nothing. That would send me round the twist that would"*

However, there was no evidence from Martyn's interview to suggest that the lack of sleep he identified was perceived to be a low mood 'trigger' as it was with high mood. Typically, participants described that when low in mood, having more sleep, or trying to sleep more, both contributed to decreased PA due to reduced waking hours, and increased SB when awake but trying to sleep which was perceived as having a negative impact to mood:

Low mood + trying to sleep more/ more time in bed → decreased PA + increased SB

For a high mood episode however, the change in SB was less clear, as although there was a perceived increase in PA, there was also more time awake, which appeared to result in either an increase or decrease in SB depending on the individual's behaviours:

High mood + more time awake → increased PA + increased OR decreased SB

Other triggers that were reported as tipping the balance and causing or significantly contributing to a mood episode were travel, adverse or unexpected events and stress, and that these triggers could be both low or high mood triggers, generally

related to ‘doing more’ or ‘doing less.’ For example depending on the nature of stress experienced, this could cause an increase in PA, or an increase in SB. This was summarised nicely by Abbie, who said:

Abbie: *‘‘my depression, it manifests again very similar to the mania, urm, at first, and you never know which way I’m gonna go with stress…I cannot do confrontation, I cannot, it sends me absolutely mad, like I will literally have to be restrained…unable to sit down or stop…or I’ll go the other way where I’ll probably cry for four weeks and not do anything.’’*

Subtheme: Medication: A gatekeeper to activity

Medication was identified as something that also contributed to shifts in balance, and related to changes to PA (often specific exercise) or SB levels, particularly regarding PA and high mood:

Jane: *‘‘if you’re on the wrong medication and you’re too high because of it then you’re going to be really, really active, so, medication does have a massive part to play in it aswell.’’*

Medication was also regarded by several participants as something that contributed to engaging in more SB and less PA. For Catherine, this difficulty to engage in more PA was perceived to be related to low mood, which was due to her medication:

Catherine: *‘‘it’s difficult to motivate yourself at times, especially with medication and urm, I’m on Olanzapine at the moment, which does make you quite urm, fatigued…it sucks motivation and energy as well…I think meds can impact on…I get quite low because of the weight gain and urm, that impacts on you when you’re thinking about doing physical activity as well, it causes quite a lot of weight gain Quetiapine does as well. And urm, obviously exercise is useful in trying to deal with that as well but at the same time…*[laughs] *it goes in a bit of a cycle.’’*

Whereas Rose and Callum simply refer to feeling ‘sluggish’ or ‘hungover’ and not ‘bothered’ thus affecting their activity levels and motivation to be more active, implying more time sedentary:

Rose: *"first thing in the morning I can be a bit sluggish for the first hour. And I think they say that it's like the effect of the tablets that I take at night."*

Callum: *"I can just stop, I wouldn't do nothing…the medication…I'm on a lot of medication."*

This was viewed as a negative impact of medication as medication was being described by participants as necessary, however causing fatigue/ lethargy/ a lack of energy, which is a further example of struggling to maintain a balance between PA, SB and mood. A lack of energy is something that was consistently identified as a barrier to specific exercise. Catherine also describes a vicious cycle of medication impacting on her motivation to engage in PA, or exercise, however acknowledges that engaging in this would combat the negative impact on her mood from the perceived weight gain due to the medication, again describing a struggle to maintain a balance:

For example: *medication use to stay stable → medication affects motivation → engage in less PA → weight gain → low mood regarding weight gain*

Participants appeared to notice this impact on exercise more than just general day-to-day PA. This could again be due to the terms being used interchangeably, or from a lack of awareness of general PA as it is embedded in routine, or more unconsciously carried out.

However, for participants who felt their medication worked well for them, it was perceived to have a positive impact and contributed to overall feelings of mood stability, helping to maintain balance:

Martyn: *"The only thing that I've got now, and it works for me, is lithium... It's, it's worked wonders for me."*

Holly: *"I've been on the dose of Lithium that I'm currently on since the year 2000, and urm, as long as like I keep an eye on things, I'm relatively stable I think."*

Carol: *"I've had to make the effort and seek help, medical help, if I felt I was becoming unwell. And, urm, going on lithium, having lithium medication."*

Sarah: *"the gym is get there, do it,* [sighs] *urm, I dropped down to go to the gym once a week and I kept thinking oh well when this happened I'll do more or when this happens I'll do more and I knew that my mood was… lower. I had a medication change, so I was waiting for that to sort of get a bit more…energy."*

Holly, Carol and Martyn all describe their Lithium medication as being significant for helping them to remain balanced and stable. However, they also refer to 'keeping an eye on things' and 'seeking medical help' if necessary, indicating that medication is not perceived by all to be enough on its own to maintain balance, and that aspects of behaviour also need to be monitored to try and maintain balance, with Sarah specifically referring to exercise. Given that participants were not asked directly about medication, but many felt the need to discuss medication in an interview on PA, SB, and mood, this implies a perceived relevance of medication being a gatekeeper for their activity and being either a positive or negative presence in the relationship between PA and mood in particular. Therefore, the relationship is complex, uncertain, changeable, and multi-factorial.

Subtheme: Determinants of volition

The term volition refers to the power of using ones' own will, and so in this section, the term 'volition' therefore represents participants' choices to engage or not engage with PA and SB that can be interpreted. Exploring volition offered a valuable insight into PA or SB. Volition was very closely related with motivation across the interviews, however this section will focus on practical and conscious reasons why participants engaged with or did not engage with a form of PA (including exercise) or SB.

Volition appeared to impact on behaviours that were considered 'routine' and were perceived to contribute to an overall balance of PA, SB, and mood, as routine was something that participants felt they had to try and maintain.

Dog-walking for example was described as a regular and necessary form of PA by many participants, which was also considered as exercise that was engaged with because it was 'required' for the dog, rather than necessarily wanting to keep fit and healthy themselves, which is required for the term 'exercise' to apply:

Susan: ''*Apart from walking the dog…I tend to walk him twice a day…if I don't walk him, I do…I don't repeat this to anybody but I do miss it.* [laughs]*''*

Martyn*: ''I get up in the morning, we've got a dog, so yeah, up gotta take the dog out…I don't do any regular exercise other than I walk the dog twice a day''*

Joanne: *''I tend to walk the dog quite regularly as well so I do, something. When I'm low I tend to walk the dog more than going to the gym''*

Carol: *''I can, take him out…and just sit, and then walk him a little way, and sit and talk to him, and that sounds silly doesn't it. You can't tell anybody anything…It's enough for me to…pull myself together.''*

Helen*: ''Well, my dog isn't desperate. I can walk my dog to the newsagents and back and she's fine, but I go with a friend and my sister, their dogs need a bit more but I go for the company and the activity, and the fresh air. And the routine.''*

Catherine: *''walking the dog is about as much exercise as I do''*

These quotes show that many participants perceived dog-walking as necessary, which also happened to be a form of PA and for Carol, a form of SB also. Susan, Hilary and Carol also elude to additional benefits relating to mood from maintaining this routine. The identified social benefits and a sense of enjoyment from being outside and being active demonstrate the perceived positive impact of engaging in PA which was perceived as 'necessary', and show how routine PA can contribute to maintaining balance in relation to these additional benefits. The above examples suggest that whilst a routine including perceived 'exercise' is acknowledged as being beneficial for health, it is not necessarily the main reason for engaging in the activity.

Routine was one of the most identified volitions for engaging in any PA, including specific exercise:

Holly: *"I have a goal where I try to urm, the Pilates and the running two or three times a week and I try to schedule times for that, but it doesn't always happen, urm, and yeah, so it depends on what goes on but I do have a bit of…a normal plan."*

Necessary tasks such as household or general tasks, were also identified as part of the importance of routine which required being physically active to complete and notably, Sarah indicates that PA gave her more energy to continue to be active:

Sarah: *"No doubt that… the interplay of those things, physical activity, the being outside, and it would also mean that I would like come in, and I would clean the house a bit. Because my energy levels would be up."*

Carol: *"But routine is very important. I tend to do a lot of washing, urm, baking… Gardening, I love gardening. Urm, tidying up, putting things in the right place. I take my grandson from school about three of four times a week as well."*

Everyday 'necessary' PA was also considered in addition to exercise by some participants and the combined positive impact of a routine maintaining balance:

Hilary: *"I have found that to keep myself more stable, I need a routine. So my routine is that…I kind of potter around, do a bit of cleaning and whatever…and basically fairly sort of, shopping, Thai-chi, things like that. It's, fairly sort of…it's routine."*

Abbie: *"I love a routine. I do love a routine… it's really quite therapeutic for me to write in the day, like every half an hour, what I'm doing. So I can plan whether I need to clean the house"*

It was observed that routine was perceived as more important for encouraging and maintaining PA and a stable mood by the women participants in this study, as three of the four males interviewed eluded to the absence of a set routine actually being freeing and flexible:

Richard: [In reference to cycling] *"just when I, when it happens really. It's hard to do it in the middle of the day. But…other than that it's, how it works out. I don't plan it, I*

don't plan anything really…I have no routine at all, no…if I was with a partner or anything. I'd have to be more structured. But, urm, that's why I'm not with a partner."

Callum: *"I get distracted quite a lot. So if I'm…if I'm here on the computer, and I think, I want a cup of tea, then I'll make the tea and then be out doing stuff in the garden. I'll use my computer, or I'll go out the front, there's no pattern to me…I don't do any, urm, physical exercise. I do go get a walk now and again…there's no…like a set physical routine."*

Richard and Callum describe feeling free from routine and enjoy the convenience of being able to do what PA activities they like when they like. Martyn's experiences of routine and PA however indicate that although he keeps himself regularly physically active every day, there is no set routine for engaging in this activity, and this PA is driven by a seemingly physical 'need to be doing something' rather than using PA to maintain a routine:

Martyn: *"Well I've, I've got a shed full of tools out there,* [points to garden] *I've got a classic car under that car-pull over out there,* [points to garage] *I've got the garden to do, there's DIY to do…so there's always something, which I prefer to do. I could not just be, sit here and do nothing. That would send me round the twist that would…I need to do, something."*

In contrast to the other males interviewed, Ben perceived a routine of specific exercise as well as regular PA in the form of household tasks such as shopping to be helpful for maintaining his wellbeing:

Ben*: "I've been doing tai-chi for almost two years now, and I do that religiously…it gave me some physical exercise. So, I've been attending sessions every single week. Urm, it was also, beneficial because…to me, exercise has got to be something practical…it's not just to ride around the block and work off a sweat, it's to do something practical, like I'll go and do my shopping on my bicycle."*

Routine was identified in regard to engaging in SB. Again, mostly the females interviewed perceived these routines as beneficial, acting of their own volition to engage in SB that is perceived as helpful. Participants directly described how a

routine involving certain activities spent sitting was beneficial to them for maintaining a stable mood:

Rose: *''I tend to sort of get to eight o'clock, and then just do quiet things like read or maybe watch the telly or something...I'm not really one to walk in the evenings, because I tend to stop and you know, calm down and stop doing things. Mentally just, read or whatever.''*

Hilary: *''so, evening, I sit around reading a book…pretty much that sort of thing''*

Callum: *''to try and keep stable I urm…I watch black and white films…I just like black and white films, and I find them relaxing, sometimes I don't relax if I'm in bed.''*

Abbie: *''So I try to get up and urm, put on like…really old school stuff and sometimes I'll nod off down here…I don't necessarily watch it, but I like the noise to lie and listen to. I listen to a lot of podcasts and things like that.''*

In these examples, routine SB appears to play an important role for these participants in balancing mood by allowing time for relaxation and calm before going to bed, with Abbie and Callum going on to say that they engage in SB that comforts them when trying to fall asleep. These examples therefore provide multiple reasons, or sources of volition, for engaging in SB routinely such as to aid sleep, to relax and calm down, and as a coping mechanism for managing mood. The pattern linking these quotes together are that they all involve routine SB that is enjoyable and serves a purpose, and therefore providing a positively viewed relationship between SB and mood maintaining balance.

Across all interviews, participants also expressed their thoughts regarding their free will and choice to not engage in a type of PA, including exercise, for example:

Finding something pointless, repetitive or boring:

Ben: *''I couldn't sit in a gymnasium on an exercise bike and just pedal away, I think that seems pointless.''*

Rose: *''So I try and do the gym but I get bored after a while, because it's very repetitive isn't it''*

Eleanor: *"*[In reference to attending zumba without a friend] *I should but I don't it's totally boring."*

Changes to priorities or commitments:

Sarah: *"pre-kids I would walk. I loved hiking and I would just go off, you know, for a day, walk, and that would help me a)relax and b)think and of course having kids that's not as easy so running sort of has, filled that…Children, weather…you know"*

Not having the time for PA/ exercise:

Holly: '*"it's a tricky thing when I'm unwell it's normally because I'm busy and finding the time to do these…is hard. But I do try to keep time aside…It is, it is mainly the time."*

Abbie: *"And I've thought every week, should I cancel it because I want to go, but my life just dictates…I'm so busy. But I find when I go that I really enjoy it, you know I enjoy exercise."*

These quotes can be considered as evidence of barriers to these participants engaging in a particular type of PA (including exercise) or just engaging in more PA generally. The examples relating to changes in priorities and commitments can also be considered as changes to routine, which appear to have a knock-on effect by decreasing PA levels if, like Sarah previously described, PA is normally incorporated within a routine. In this perceived relationship, it would appear that PA and SB are brought into an established routine, which then impacts on mood, however there was no evidence from across the interviews to suggest this relationship is only one directional.

Identifying different sources of volition provided an insight into the relationship between the thoughts and behaviours of participants in the context of conscious and somewhat unconscious PA or SB engagement. Many participants were able to relay routine PA and SB behaviours during the interview, but considered these as

something that they just ‘got on with’ or ‘had to do,’ which provided an insight into the relationship between PA in particular, and volition.

Subtheme: Internal & external struggle

Participants reported varying levels of motivation to engage in PA both when feeling ‘well’ with their mood, and when feeling their mood was particularly high or low. This was discussed both in terms of internal struggles to conjure up or maintain motivation, as well as external struggles relating to factors out with a participants control, such as accessibility, weather, injury etc. Motivation was viewed to contribute to the overall effort of trying to maintain balance between PA and mood.

Susan: [In reference to exercise class] *‘‘The less motivated you are the less you do. And as far as I’m concerned motivation goes alongside mood. Common problems are I can’t be arsed’’*

Joanne: *‘‘occasionally I feel I really can’t be bothered and don’t go but generally I try to stick to the same three days a week…But that’s sort of slowed down in recent years…I suppose it’s motivation partly, and, it’s made a difference the fact that I don’t go to any classes anymore.’’*

Callum: *‘‘Yeah I sit outside as well in the garden and drink my tea and such. But as for…the only exercise I get is going to the shop. Exercise is urm…not for me.’’*

*A*cross the sub theme of internal and external struggles, a number of barriers and facilitators and/or motivating factors for engaging in PA were extracted from the data. These were explored directly using prompts from the topic guide, and so were widely evidenced throughout all transcripts. As the data pertaining to these was extensive, and because these have previously been explored in depth in other studies (Busch et al., 2016; Firth et al., 2016; Shor & Shalev, 2016; Sloan et al., 2018; Soundy, Stubbs, et al., 2014) a summary list of all identified barriers and facilitators/motivators for engaging in PA are outlined below in Table 4.5.

Table 4.5 Summary of perceived barriers and facilitators and/or motivators for engaging in PA

Barriers	Facilitators and/or Motivators
No access to services / facilities and/or high cost	Having access to services / facilities at affordable cost
Low energy / fatigue / feeling low in mood	Increased 'energy' when high in mood
Having no one to go with	Having some 'time out' to escape (people, environment, stress) and to be alone
Avoiding contact with people	Socialising
High mood a barrier to structured PA/ specific exercise	Mood regulation, improvement, and stability
Physical health problems	To combat physical health problems / improve strength
Not having the time for PA	PA that offers flexibility
Having anxiety or confusion over what to do (particularly at the gym or in an exercise class)	Enjoyment
Poor weather	Good weather, nature, and greenery.

Most of the reported facilitators/ motivators and barriers in Table 4.5 could also apply within the general population, for example weather, cost, access to services, and time. However, there are some that can be considered as specific to people living with BD, such as:

Low mood as a PA barrier:

Abbie: *"it warps everything in your life…because you're so low in mood and you can't tell yourself, you know"*

Jane: *"it's not as easy to exercise when you're low. At all. Because you just… actually having the self motivation to get up and get out and get involved, is hard."*

Hilary: *"I find it harder when it…you go a couple of times and then I think, I don't want to go again. And then that's the start of a depression phase so it's a case of forcing yourself and sometimes I think I'm not going to enjoy this, but I am. It's that will power when you're feeling like that."*

Ben: *"When I'm very depressed, I…often deter from going on my bicycle, ridiculously for non-existent problems pop themselves into my mind like, oh the gears aren't working properly, or, the chain needs oiling or replacing, or there's something wrong with the breaks. When in reality, there isn't"*

Jane: *"*[in reference to yoga] *So that is, it's harder to go and be part of a group…in the back of my mind I've got, you are not worth this. You are not worthy of feeling any better, you deserve to not do this. You deserve to struggle doing this. It's like little demons on my shoulder going 'ha, you'll fail, I'm going to make sure you fail, ha.* [laughs]*"*

Having anxiety, or a concern over engaging in PA:

Joanne: *"my confidence is always affected when I've been in hospital. When I'm low my confidence is not very good so that, a bit of a barrier is going to the gym…I would go in, feel a bit intimated"*

Susan: *"it's fine going out with the dog, because that's, urm, an accepted activity…I mean…the path needs weeding…last time it needed the weeding…I found it really difficult to do. To go out, and…It, it's weird."*

Jane: *"one day I will understand it all, or, I'll be really flexible, or I'll be really agile, and then the next day it's gonna be hard for me to actually move my arms above my head because the depression's just taken me so low."*

High mood was a barrier to specific exercise, but a simultaneous motivator for PA:

Richard: *"I mean* [pause] *it would never…when I'm manic it would never occur to me to get on a bike or anything. I'd probably drive into somebody. But maybe if you're less, like hypomanic or something, I dunno."*

Joanne: *""in terms of exercise I'll totally stop going to the gym…And I know for some people it becomes, sort of slightly higher the more they exercise so they will sort of go faster on the treadmill or whatever, I just don't even bother going…I tend to go off somewhere else…walking everywhere."*

With the above examples, there is a distinction made between exercise and PA. This distinction is made specifically in relation to high mood, where participants recognised moving around more than usual, and being more active, (PA) however that this was not a structured or planned activity (exercise). This was also identified when participants talked about feelings of increased energy during high mood as a motivator or facilitator for general PA:

Jane: *"I carry, a lot of things, very heavy. I think that I've got boundless energy…So it manifests itself in that I move around, a lot, I move quickly people can't keep up with me…I have increased energy I won't want to sleep I can't slow down."*

Sarah: *"just boundless energy…in that sort of manic episode or if anybody hears that I have energy going on beyond three o'clock"*

Carol: *"well just in me personally…I just get a lot of energy and just want to talk to everybody, I want to do lots of things all at the same time…make a lot more things, I'll do more knitting, more baking, just general things like that."*

These examples indicate that the increase in PA was perceived to be a result of high mood, and specifically the increase in energy felt during high mood. These examples also indicate that the intensity of the PA engaged with is relevant in relation to high mood, as participants talk about not being able to 'slow down' and the energy being 'boundless' and doing 'more' than what is typical or usual for them.

Many of the barriers and facilitators/motivators identified are the opposites of each other, for example good weather as a facilitator/motivator and bad weather as a barrier. Notably, some items appear as both, indicating that some factors, such as physical health problems, the social aspect of PA and avoiding people/ having some time out can be a barrier or a facilitator/motivator for different people. Additionally, these factors were considered by some participants as both a barrier and a motivator depending on their current mood:

Abbie: *"[*In reference to zumba] *when you're actually in depression, getting there yes is hard, but once you get there and you're in the middle of it it's so therapeutic to be able to just let yourself go…So for me if I was in depression to go right, I know exercise is going to make my mood better, that would take a lot for me to do."*

Jane: '*'It's a weird thing when you're part of a group who exercise and one week you can do something really well and the next week you can't even remember your name, so, doing anything well, at that point, is gonna be a little bit of a–no, that's not going to happen."*

Holly: *"And I'm also mindful that when I go out running, if I am a bit unwell and I feel uninhibited, I'm likely to be smiley at everyone I see, urm, and those are risk factors for me, I tend to be, kind of, talking to people and kind of making things worse...But things like the Pilates are more flexible and a bit safer I guess because I'm not going to be around other people."*

This indicates that the factors identified in Table 4.5 are not perceived to be permanent or rigid, but things to be managed or balanced in relation to mood to try to encourage regular engagement with PA, a key finding of this study.

Many of the above quotes regarding motivation are again evidence of participants acknowledging a firm awareness that engaging in PA, particularly exercise, will make them feel better when low in mood, however this knowledge is not enough to encourage them to go on to engage with PA if their mood is particularly high, or particularly low, an important finding that was evidenced across the themes (ie. internal struggle). These quotes indicate that the more severe the depression, the less likely engaging in PA is perceived as a feasible or realistic tool to use as a way of trying to improve symptoms. This is important for considering the use of PA or SB interventions targeting people with BD and making sure the interventions are realistic and maintainable. Understanding both motivational issues and different determinants of volition may be key for the success of these interventions. In addition, Holly describes having to be ‘mindful’ out running when experiencing high mood, as this type of PA brings with it risk factors such as social engagement that can be unhelpful when experiencing high mood, and so here it seems the factors associated with running may be what is perceived to be maintaining high mood, rather than the PA itself, or potentially the PA in addition to the social aspect of the activity.

This section shows that participants found it difficult to distinguish between whether engaging in a particular type of PA was having an impact on mood (both high or low) or whether the other factors that accompany the PA had more of an impact, or the interaction between PA and the accompanying factors was what was important in relation to mood, further highlighting the complexity of the PA and mood relationship.

4.5.2.2 Main theme one: Changing physical activity & sedentary behaviour levels

All participants identified a link between how physically active they were, and their mood, and reported changes in how much time they spend sitting and lying down (SB) in relation to their mood. This main theme therefore continues the exploration on from the overarching theme of 'trying to maintain balance,' by exploring the various changes to PA and SB levels experienced, that were perceived to be related to a change in mood: whether this be a particular aspect of mood (for example sadness, or anger); or an overall mood state (for example depressed or (hypo)manic). The thematic map below (Figure 4.6) shows some of the key codes that make up this theme. These are discussed throughout this section. The map shows the connections between some key subthemes and visually helps to demonstrate the concept of balance that is referred to throughout. The subthemes of 'increasing PA' and 'decreasing SB' are presented together, and 'increasing SB' and 'decreasing PA' are presented together. This is to demonstrate the particular connections between these sub-themes, and to highlight how an increase in one, was often perceived to be related to a decrease in the other despite being separate constructs (Tremblay et al., 2017).

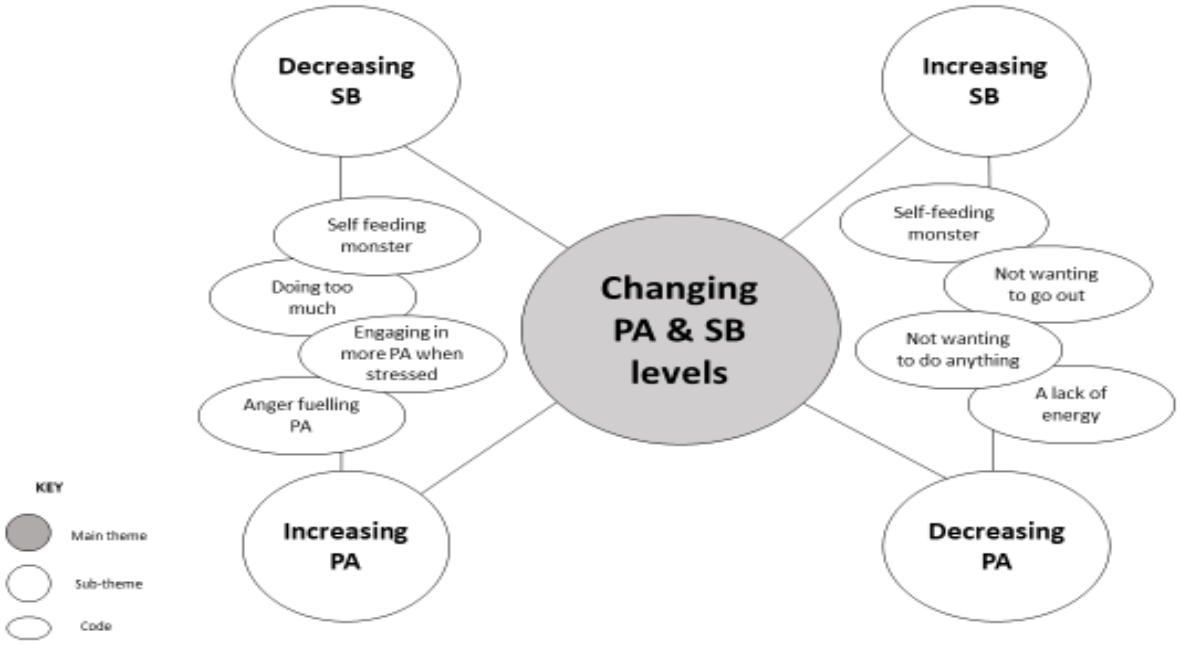


Figure 4.6 Thematic map 'changing physical activity & sedentary behaviour levels'

Subtheme: Increasing physical activity levels

Feelings of anger were identified by Rose and Hilary as mood changes that had resulted in a sudden increase in PA:

Rose: *"if I get really angry that will fuel exercise as well…it's just a way of urm, to release the anger…but I did notice the anger was fuelling me to do something physical."*

Hilary: *"I was angry at myself. I don't know if this makes sense, but I found that because I was so angry at myself, because I thought I was slow…I wanted to take it out on rushing and making everybody else move, I mean, I became more and more into the activity"*

In these examples Rose and Hilary have felt anger and then this has resulted in becoming more physically active as a means of processing and managing that anger. Participants also described situations where not being able to carry out a specific PA as expected had caused frustration:

Martyn: *"I used to love to swim…I'll go in the slow lane. But you get some numpty in there that's pushing you out the way and you think, 'If you're that fast mate get in that bloody lane'* [laughs]*"*

Hilary: *"I signed up for a fencing course…that's obviously good activity, doing the 'shh shh shh'* [participant imitates fencing motion and noise of fencing sword] *with it but it didn't work like that because you have to learn all the bits first. That wasn't good enough for me, wasn't quick enough* [laughs]*. And I really, you know, would have enjoyed it you know."*

With these examples, Martyn describes frustration at the situation surrounding the PA, rather than the PA itself due to other people being inconsiderate, and Hilary is frustrated at having to learn a new skill before being able to engage with the PA, and the PA not being quick enough. Both of Hilary's examples of anger and frustration were described specifically in the context of her experience of a hypomania episode, which commonly produce feelings of irritation and frustration at not being able to carry out certain tasks which is what was described here specifically in the context of PA. Unlike the previous examples of anger potentially increasing PA, these experiences demonstrate frustration due to an unwanted decrease in PA.

Similarly, feelings of stress were also considered to be related to an increase in PA or exercise to manage stress:

Rose: *"[*In reference to walking] *And also, I find I can de-stress as well. So I don't take a phone or anything with me, or maybe I have it on me but it's in a pocket switched off, but urm, it's just to get out"*

Joanne: *"And I do think going to the gym is a way of managing stress as well"*

Eleanor: *"Just walking, walking's supposed to be one of the best exercises for you, isn't it, you know...And, the stress. And I think stress, has got a lot to do with it…not just in bipolar, people in general."*

This is important considering that stress was also a reported mood trigger across the interviews, with the above examples indicating that PA can be helpful for stress management and is an outlet for unpleasant emotional responses that are

characteristic of (hypo)mania such as anger and irritation. With anger, it could be considered that the mood change occurred before the PA increase, whereas with the irritation/frustration, it appears that this occurred due to not being able to engage in PA, indicating a complex relationship between mood regulation and changes in PA which is difficult to manage.

Subtheme: Increasing sedentary behaviour levels & decreasing physical activity levels

Low mood symptoms were described in relation to an increase in SB and decrease in PA. When describing these experiences, participants referred to a lack of 'energy' accompanying low mood as potentially causing their observed decrease in PA:

Joanne: *"*[in reference to low mood] *I think my energy levels are lower as well which doesn't really help."*

Catherine: *"And as I say depression can make you quite lethargic"*

Sarah*: "When I'm low there's no energy at all…being low just having very little* [energy]. *Lots of sleeping, or no sleeping but not being able to move, or, you know…it happened over Christmas and my mood is definitely lower in the winter…And my energy levels perhaps more than my mood."*

Sarah identifies winter as something that contributes to her low mood and had also referred to not being able to keep running in the winter months later in the interview. Richard also refers to a lack of motivation as being connected to not engaging with his usual bike ride:

Richard: *"When I'm low…I just haven't got the energy or the desire to do it and I just don't want to. I have to really force myself to do it.'*

The lack of energy appears to affect motivation and the perceived physical ability to actually engage in PA, indicating a general sense of internal struggle and needing to

feel energetic to be able to engage in PA, particularly exercise. Participants went on to describe this in terms of not wanting to do anything, but to sit or lie down instead:

Abbie: *"to sit down, do nothing and actually coming through that depression on my own, and it just went on and on and on'"*

Carol*: "I just don't want to do anything."*

Catherine: *"you can literally just get in bed and not want to do anything"*

Hilary: *"I'd just sit. Just not do it…I just wanted to go and sit and be left alone…I just sat and did not much really, I did nothing. And it got worse, and worse."*

The above examples incorporate a lack of motivation, low mood and low energy as being related to a decrease in PA, and an increase in SB, whereby participants have identified depression as a state of almost constant SB. Common points participants made in these examples are not going out, not moving or doing anything, and wanting to be left alone. Sarah spoke of 'giving in' to the depression:

Sarah: *"if you're depressed and have low energy and low mood, as awful as it is, you can kind of, give in to it [pause]. There's something that's enticing as well in the early stages of it. Urm…you know, even if you're not focussing on anything you can lie there and have the television on."*

This example offers further insight into why PA may feel unhelpful for a severely low mood episode due to the *'enticement'* Sarah describes, and a real internal struggle to obtain motivation. Further, Callum said it *'knocks you flat,'* indicating increased SB is perceived as an inevitable outcome of depression, and therefore difficult to even try to tackle through PA, even with something he would usually find pleasurable such as gardening:

Callum: *"Because, depression and…well I mean knocks you flat don't it, you don't want to do nothing…even out there in the gardens if I'm feeling low, I won't go out. I can't be bothered."*

There was also ample evidence to suggest the relationship between PA, SB & mood is a *'self-feeding monster,'*

Ben: ''*I think that becoming more active does lift mood, that's been my general experience of it…it's been my experience, a self-feeding monster''*

and not necessarily one directional, i.e., 'if I am lower in mood I will sit more. It was suggested more time spent sitting may lead to lower mood, as well as lower mood likely leading to more sitting. The same was evidenced for PA in that the more physically active participants were, the better their mood generally, and the better in mood they feel, the more physically active they are likely to be. The following quotes evidence this concept, highlighting the complexity of this relationship, and the difficulty for participants to distinguish the roles of changing levels of PA and SB in relation to mood in the relationship between PA, SB and mood. Most spoke specifically of low mood, increased SB, and reduced PA:

Sarah: *''they probably feed a little bit off each other…I've had a few weeks where my energy levels have been lower, and my mood maybe slightly lower, and I've done less exercise. But it's not, entirely sure which way round it is…But I can link them''*

Susan: *''The less motivated you are the less you do. And as far as I'm concerned motivation goes alongside mood.''*

Catherine acknowledges this relationship in terms of keeping well:

Catherine: *''I think urm if you're feeling better you tend to want to do more…I'm pretty sure really that the more you do, the more you feel like doing, I think that's probably quite true as well.''*

And Holly and Abbie address both sides of this relationship in terms of high and low mood, and the cost of doing too much or not doing enough for mood regulation:

Holly: *''I think that when I'm not active at all I'm more likely to feel low, and I think that when I am active, that can make me feel good, but when I'm too active and too*

busy, and I don't have enough time to process things, then I'll become overwhelmed and then I can't slow them down and start to go to high.''

Abbie: *'' if you do start sitting down, you know, you will get low mood without a doubt....And it is a big problem when I'm high…I cannot sit''*

Although PA is a different concept to SB and an increase in one does not necessarily mean a decrease is observed in the other (Tremblay et al., 2017), the above examples showing extremes indicate an increase in one likely results in a decrease in the other, for example comments such as 'I did nothing', imply an increase in SB, and a decrease in PA being perceived to be related to symptoms of low mood.

4.5.2.3 Main theme two: The impact of physical activity and sedentary behaviour

Evidence of the positive and negative impacts of PA and SB in relation to high and low mood in BD were abundant across the interviews. Participants challenged the perception in health messaging that PA always has a positive impact in relation to mood regulation, and that SB will have a negative impact (see Figure 4.7). This theme therefore describes this evidence and interprets through the reporting of the perceived 'positive impact' of both PA and SB in relation to mood, as well as the perceived 'negative impact'.

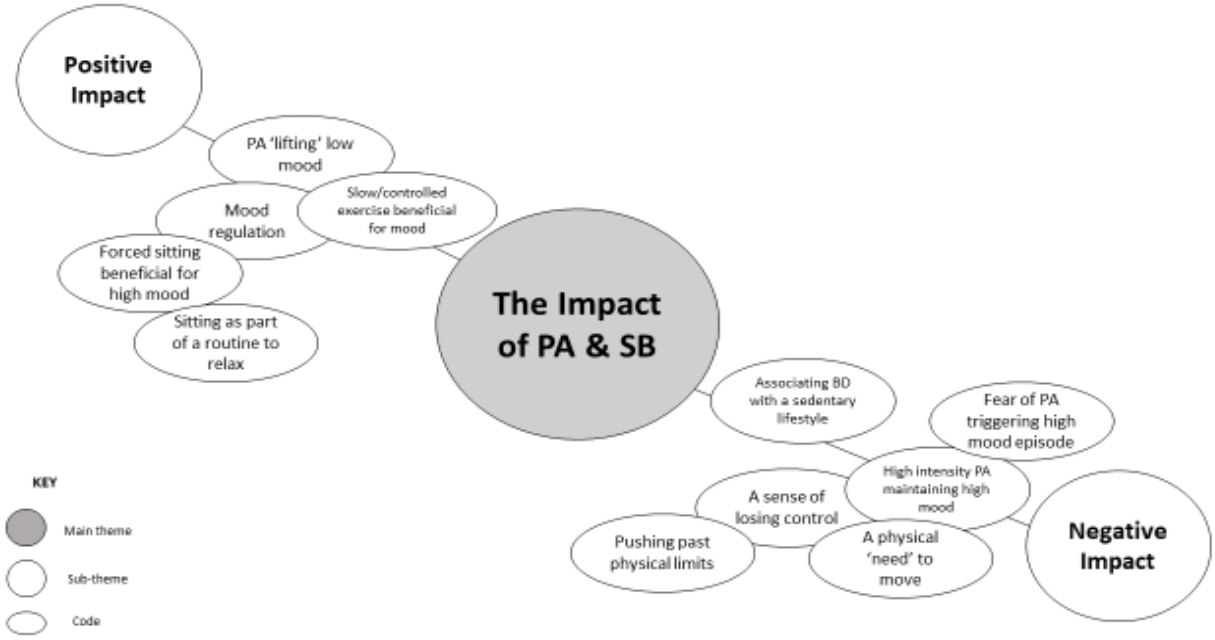


Figure 4.7 Thematic map 'the impact of physical activity & sedentary behaviour'

Subtheme: Positive impact

In support of the previous literature indicating that PA may have a positive impact on depressive symptoms in particular, participants described their experiences of PA as helping to 'lift' their low mood:

Richard: *''My mood doesn't lift when I decide to go on a bike ride, it lifts after I've done the exercise''*

Carol: *''if I'm feeling low, to get myself to do something, physical…go for a walk, go for a swim, take the dog out, that can kick start my, being how I should be…I think if I'm active, I…ditch any low mood I have.''*

Jane: *''I definitely use exercise to regulate my mood. If I'm low in mood, the best things for me to do is exercise…it's really useful when I'm low if I can find a way to exercise''*

Abbie: *''I've tried Zumba in the past...It's really high energy, the music is loud, and when you're actually in depression, getting there yes is hard, but once you get there and you're in the middle of it it's so therapeutic''*

Sarah: *''I think if I was having…a slightly worse day then the running would help. I could put it into that''*

Rose: *''it's nice to see what makes you feel better so yeah, exercise''*

These examples could be interpreted as low mood lifts specifically after an increase in PA, as PA is being acknowledged as having produced, or at least contributed to, the change in mood. Abbie also identified the music as having a positive impact, as she describes the collective experience as being 'therapeutic'. PA can still be considered an outlet as in the previous theme, as Sarah refers to 'put it into that' and 'it' could be taken as stress or anger, given she also refers to a 'bad day'.

There was a sense across the interviews that when PA and mood are considered balanced, that the right type of specific exercise could be valuable for mood regulation and maintaining stability, creating a lasting positive impact on mood.

Joanne*: ''I try to go to the gym regularly. I do think it makes a big difference…it is kind of, calming…I think that's very important really.''*

Holly: *''I normally find that really helpful because it will be a very slow pace* [Interviewer: Some people have said that, urm, that when they feel quite unwell that they need something quite slow and steady to help manage their mood rather than something fast paced]*…I would, I would agree with that…if I'm not feeling very well and I go out for a run I usually run very slowly''*

Sarah: *''that's why running was good it ticked every box…even on days when you have a bad run and you give up halfway round, you still feel better than if you weren't doing it all…so it needs to be quite physical''*

Abbie: *''So, obviously when you're in low mood you don't have to worry about being high or getting too high because you want to get to that point anyway, so I've tried Zumba in the past…I suppose that sort of stabilizing of mood. Walking I find clears my head.''*

Rose: *''I think because I've actually been very stable for quite a long while now…And I'm sure that, you know exercise comes into that.''*

Catherine: *''I know that exercise is very good for you as well with mood and things, walking the dog is about as much exercise as I do''*

Ben: *''I have been a keen cyclist over the past few years as well, I find that helps a lot as well.''*

In addition to identifying a type of PA that was beneficial for mood regulation, a few participants specifically identified slow and controlled activity as having a particularly positive impact:

Joanne: *''Because, the weights are heavy, it is tiring, and I tend, like I said I tend to stay sort of static rather than rushing around, so, it does sort of slow me down and make me concentrate rather than trying to run as fast as I can on the treadmill''*

Two participants specifically spoke of Tai-Chi as a slow controlled exercise that helped with mood regulation and stability:

Hilary*: ''[In reference to Tai-Chi] It's both. It's mood, but it's also good to improve my core strength''*

Ben: *''I've been doing tai-chi for about two years, and one of the things it has taught me is, breathing. Breathing properly. And when I feel like I'm being manic… at the same time, it gave me some physical exercise… I'm sure that the tai-chi has been extremely beneficial in keeping me stable.''*

Richard and Holly considered 'exercising of the voice' to be a form of PA, and identified this as being important for them both for taking control of their breathing and concentrating on an activity, but helping to maintain balance with mood, particularly with life stress, and overall having a positive impact on wellbeing:

Holly: *''I also do Pilates, urm…that seems to help. I do other things, I sing in a choir, and I go running. Urm, so all of those things…and if you count singing as exercise, then, urm, I would really speak highly about that...And I think that was really helpful, the breathing control. A positive impact.''*

Richard: *''I'm in a choir and urm, that's good exercise by the way.''*

These exercises all combine controlled movements and breathing, and appear to allow the participant to take focus and conscious control of this to help regulate their mood as well as gaining the physical health benefits from the PA.

In addition, participants also described many instances where there had been a positive impact of SB in relation to mood regulation and using tasks that involved SB to help balance out and take control of high mood symptoms relating to (hypo)mania.

Abbie: *''I have to literally, sometimes notice it [*beginnings of high mood] *and say right I'm going to go and sit down now, have some quiet time now to get my heart rate down''*

Jane: *''she'd say* [CPN], *you're a little bit high at the moment aren't you, yes, okay so you need to enforce a sit down, break…being in a position where I have to have enforced stillness is a hard one to do, but once I've actually found someone to do that with…and go to the cinema, it's a real help when I'm high, it really does help.''*

Sarah: *''well my favourite thing is to go to the cinema. The really big loud cinema. Because I have to sit still, that I get so much input, that I can actually relax.''*

Jane and Sarah both use the example of going to the cinema as SB that helps to enforce stillness and bring on a sense of calm and relaxation which in turn helps to reduce the severity of high mood symptoms. What is unclear from these examples is the extent to which the sitting is perceived to be having the calming effect, or the darkness and stillness of the cinema surroundings and environment, or the distraction of/engagement with the film being shown that is important in the situation for helping to balance mood. Environmental factors appeared to have a role to play in the relationship between PA, SB, and mood, and that potentially it is the integration of all these things alongside PA and SB that is important in relation to mood, rather than just PA/SB itself.

Subtheme: Negative impact

Participants also described a negative impact of engaging with PA, particularly when high in mood and engaging in specific exercise.

Abbie: *''when I do cardio exercise, maybe be mindful of what you're kind of listening to. All the stimulation of other things as well like playing fast paced music, I will probably come off the treadmill bouncing off the walls, you know, whereas if I can listen to a podcast, you know or just, you know it wouldn't necessarily push me that high, I would say. But it can be such a mixture of things.''*

Abbie describes how engagement with high intensity exercise perhaps maintained her high mood and did not help to regulate her mood, although she had previously described exercise as something that helped to regulate her mood and helped to maintain stability. Abbie highlighted fast paced music, which was matching the fast-paced exercise she was engaged with; but suggests a calmer podcast would not have the same effect. Therefore, this may not necessarily be a result of the activity itself, but the associated sensory or environmental stimuli surrounding that activity, or a combination of the activity alongside these factors. This was echoed by others:

Jane: *"exercise…is a tool, but it's never taken me from a low mood to a high mood…no that's not me. A part of everything else, yes, but on its own, no, I've never went from low mood to that"*

Sarah: *"No doubt that…the interplay of those things–physical activity, the being outside, and it would also mean that I would like come in, and I would clean the house a bit."*

Ben: *"It's hard to keep control of the situation. And there have been many periods when I've failed totally to keep control of the situation because of external influences."*

This indicates a complex, multi-factorial relationship between PA and mood, which can be influenced by environmental factors.

The type of PA participants engaged with was perceived to be related to high mood symptoms experienced, with Sarah referring to a 'need to move' being negative:

Sarah: *"I'm in that, sort of, mixed state…with the mania, I might have thought I was being focused but perhaps actually just moving from one thing to the next, but I can't remember sort of duration times when I was sitting, but it would be mixed state, I wouldn't be able to just sit and watch a programme…my need to move would be increased…It would be a clearly negative thing but a very physical need to move."*

Other participants described a similar feeling of a physical need to move in terms of doing more or doing things faster than normal having a negative impact, and having no control of this:

Abbie: *''I'm on my feet all day, I'm either up at the group or I'm collecting kids and, I'm back and forth places, that can really push me, high, just because I'm doing lots…it's that higher rate of working''*

Ben: *''hypomania…yeah I feel on top of the world, I take on lots of projects, which ultimately don't get finished…Oh, renovating motorbikes, motor vehicles, urm, household projects, electronics projects, all manner of stuff.''*

Callum: *''You wanna do things, that's the main thing, you want to do things. And it don't matter what they are, you'll do them''*

Carol*: ''I want to do lots of things all at the same time…make a lot more things…I'll do more knitting, more baking, just general things like that.''*

Rose*: ''*[reference to mania] *I usually get very very busy…going from job to job, sometimes when I get particularly bad I'll not finish one job or just keep going round.''*

These examples describe how participants view these types of PA as unstructured, unproductive, and unhelpful when high in mood, despite the seemingly productive and helpful nature of the tasks being undertaken. The volume and intensity of the tasks here as well as the quickness with which they are carried out which, when coupled with high mood or mixed state symptoms of frustration and agitation, make the PA problematic, leaving a negative impact. Again, it would be helpful to know whether a structured, controlled approach to PA as described above would be helpful for high mood, however Hilary had warned at this stage of (hypo)mania:

Hilary: *''You just become more and more into the activity''*

Which was echoed by Jane:

Jane: *''when I'm high, I will push my body past the limits that I would usually go to…the kind of yoga I do is Hatha yoga so, yeah, it's slow and controlled and you use the breathing to move and you move gradually…When I'm high, I push my body further. I make the arch of my back more pronounced, I will switch my toes and then I will put my hands flat on the floor and then I will still keep going…it's like the pain receptors don't tell me that, I've had enough. They don't tell me that I've pushed myself too far so I will over stretch my limbs.''*

This could be interpreted that there is a personal and individual level at which PA, particularly exercise that is high intensity or challenging, can actually help with mood

regulation. However there appears to be a time when this stops being helpful, or positive, and can become unhelpful, and actually make things worse in regards to (hypo)mania by feeding aspects of mood such as higher energy and elation, resulting in negative consequences both physically and mentally.

This interpretation can be evidenced in that most of the women interviewed identified a fear of mania, and that PA, particularly exercise, had a role to play within that by trying not to do too much in case this triggered (hypo)mania or made an episode worse:

Hilary: *"a lot doing extreme aerobic classes and aqua aerobics and I'd go and I'd be way up, and I'd be worse. I'd get back and you'd think I'd be tired and want to sleep but no joking I'd be way up, yeah. That's something that worries me a lot, yeah."*

Sarah: *"I wouldn't want to sit down and relax...the mania might seem similar to the agitation there's the worry and the, it's not quite paranoia but there's a… something's, things are wrong, things are, something terrible's going to happen, there's a dread."*

Susan: *"if I start going, if I…can't sleep. Or don't sleep…I have been known–not recently–but I have been known to sort of get up at 4 o'clock in the morning.. and doing something…I do, I do worry about getting more...more happy."*

Joanne: *"and I go, 'right we're gonna go through these bags today' urm, so, obviously if I'm elevated in mood even…you know getting fifteen bags out, to go through them, that's gonna hurt* [laughs]*"*

Contrastingly, this fear of mania was not echoed with the male participants in this study, indicating the women interviewed considered PA, particularly exercise, as a potential trigger for high mood and therefore are apprehensive about the negative impact on their ability to maintain balance.

Many participants described a negative impact of PA physically, particularly when high in mood, such as with Jane's previous example of yoga:

Jane: *"I hurt myself physically, urm, my joints urm become under a lot of stress and pressure because of the amount that I'm moving about myself, and the amount that I carry with me."*

Joanne: *"I don't get tired, and I don't particularly get hungry. I just keep going. There's nothing telling me oh you've went too far."*

Abbie: *"So, I will push myself but then I'm in pain...I often find that's after I've pushed myself far too hard, either with exercise or with day-to-day stuff. And then I'll get a migraine."*

Abbie: *"I just keep going. It's only when I stop and sit down and I literally can't move…my children's school is down there, you know it's about…three and a half miles there and back. Urm, and if I, I often walk there and back with them in the mornings, but then I'll do it again in the afternoon as well, but I haven't eaten anything... And that's when I admitted that my mood was too high for me to function."*

Hilary: *"I started, oh, when I was manic I started this really, what do they call it…extreme aerobics, and things like that because I thought, I'm not moving fast enough and I'm almost pushing myself in a way, with this mania. Urm, and I think that was the trigger."*

These quotes are examples of participants pushing past physical limits when high in mood, not knowing when to stop, and perceiving themselves to not have the ability to stop what they are doing, which results in overexertion and is a negative impact of PA. This impact can result not only in exhaustion, but physical injury. This is again indicative that there is a crucial stage at which PA may no longer act as a mood regulatory tool for high mood, but tips into maintaining high mood with the increasing vigorous intensity of PA, and perhaps the determination and challenge perceived from the PA contributing to 'goal orientated activity,' a diagnostic criteria for (hypo)mania.

A negative impact of SB on mood was also described by participants across the interviews, describing already established factors such as weight gain, low mood, and low energy, in addition to the 'self-feeding monster' described previously, with Catherine introducing the topic by associating having BD with having a sedentary lifestyle.

Catherine: *"I think on the whole with bipolar, apart from when people have manic periods, people are, urm, you know, haven't got quite as much energy as somebody*

who doesn't suffer from the illness, and urm, you know there are a lot of people who do have more sedentary lifestyles because of it.''

It is important to recognise that although PA and SB were treated as separate concepts within the data analysis, that is, a change in one was not automatically assumed to mean the opposite change in the other, there was a general sense from the data of PA and SB being perceived in this way by participants. This is somewhat reflected in the two extremes of mood experienced by people living with BD and the episodic nature of BD, as described within this theme outlining 'the impact of PA and SB.'

4.5.2.4 Main theme three: Physical activity & sedentary behaviour changes as an early warning sign

Participants reflected on their experiences of (hypo)mania and depression in relation to PA and SB during the interviews, identifying changes to their PA and SB and particularly where this change was associated with a negative impact on mood. Collectively, these reflections can be interpreted as disruptions to the balance of PA and SB with mood, which can be considered as an early warning sign of a noticeable change in mood.

When discussing the relationship between PA, SB, and mood, and whether there was a perceived temporality between the concepts, participants appeared to struggle to comment on the relationship or conceptualise it, highlighting the complexity of the connections between PA, SB, and mood. There was a suggestion from all participants that a change in both mood and either PA or SB would be noticed together, although what way around that happens was less clear, and so the final main theme groups together and discusses the evidence of PA and SB as early

warning signs that mood is either changed, or about to change, depending on the participants perspective (see Figure 4.8 below). This theme evidences the greatest area of differences between participant views on the relationship between PA, SB, and mood. The subthemes of ‘negative impact’ and ‘positive impact’ are here discussed alongside ‘changes to PA and SB levels’ due to the connectedness of these subthemes and how they work together to explain perceptions of the relationship between PA, SB, and mood.

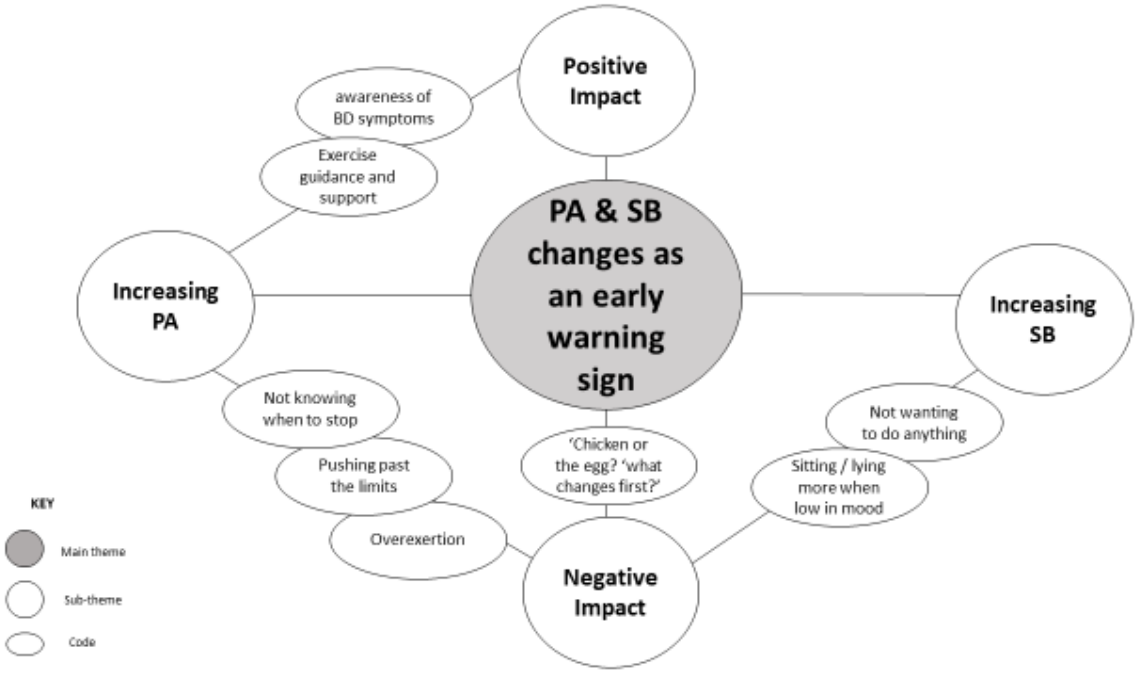


Figure 4.8 Thematic map 'physical activity & sedentary behaviour as an early warning sign'

Subthemes: The negative impact associated with changing physical activity or sedentary behaviour levels

This section explores the connection between changing PA or SB levels and the perceived negative impact this can have on mood. The negative impact of changing PA levels appeared as particularly relevant in relation to (hypo)mania, for example Joanne stopped engaging with structured exercise:

Joanne: *''There have been, in the past, times when I've become unwell and looking back…I've stopped going to the gym''*

And Sarah describes the unproductive nature of PA during (hypo)mania, even when medication and mood triggers such as sleep are seemingly balanced

Sarah: *''I'm not sure when it tipped from just being productive, into something else…In fact that, you know, the starting thing for the, that sort of manic episode or if anybody hears that I have energy going on beyond three o'clock you know even when I'm completely well and I'm sleeping well or I'm not medicated''*

And also states that it is difficult to identify any order to PA and mood changes:

Sarah: *''it's not, entirely sure which way round it is. But I can link them, and say well I haven't done as much exercise, and my energy levels are low so lets try and do some more exercise and see if that will…and certainly if I didn't, then I'd probably do even less exercise. So I haven't… it's a…I am aware of it.''*

Other participants said they or those around them notice changes in their PA behaviours prior to a change to high mood:

Jane: *''I think, that, I don't notice when my mood is elevated…I exercise more first, it's, it's the amount that I carry, the amount that I walk about and the amount that I carry with me…That's the thing that changes first.''*

Joanne: *''my boyfriend's said to me fairly recently actually that I walk differently when I'm, becoming high. It's not so much that I walk faster, I just sort of walk in a different way, I tend to stomp more. But I think generally…my mum would notice that I would be sort of livelier and do things more quickly.''*

Contrastingly, some participants felt that a change in mood preceded the change in PA or SB:

Hilary: *''I've been trying to work that one out, urm…I actually think my mood changes…before my behaviour. But I find that hard to decide, but I think that's, possibly it.''*

For Holly, this was considered separately to sleep:

Holly*:* ‘‘[Interviewer: So would you notice then a change in your behaviour before you notice a change in mood, or does it happen the other way round?] *I think it happens the other way round.* [Interviewer: So you would notice a change in your mood, before you would notice a change in your behaviour?] *Yeah…yeah. And it is sleep that would normally precede either a change in mood or behaviour.’’*

And Abbie considered this to be in conjunction to other environmental factors:

Abbie: *‘‘So for me if I was in depression to go right, I know exercise is going to make my mood better, that would take a lot for me to do. So perhaps, no the mood change wouldn’t come later, but I’ve noticed that if my mood is higher, it is when things are going on environmentally.’’*

Two participants used the ‘what came first, the chicken or the egg’ debate as a metaphor for how difficult it was to isolate a temporal order or identify specific roles and interactions for PA, SB and mood, which was viewed negatively as this made it difficult for participants to predict or control their PA/SB behaviours and their mood.

Susan: *‘‘I was…admitted. Now I don’t know whether that, they call it chicken or egg you really don’t know that it was…I’m sure it’s a combination of a lot of things… it is interesting to try and reflect back for the last week on…stuff. If you like. More particularly perhaps with the sleeping patterns...More to the point. If I’m not sleeping is it because of physical movement…why am I not sleeping, you know’’*

Richard: *‘‘And that’s why I was feeling like that, but maybe I’d…it’s chicken and egg you see…but I suppose you can tailor what you do* [in reference to PA], *taking in account of your illness, but I don’t very much…it comes back to this chicken and egg thing…I just go into this spiral of, why.’’*

All of the above examples of perceived temporality or uncertainty of PA, SB and mood changes can be considered alongside the cyclic nature of the relationship between PA, SB and mood described previously where doing more lead to wanting to do more, and doing less led to wanting to do less. This relates to the ‘self-feeding monster’ metaphor used by Ben, who also said regarding mood changes:

Ben: *"It's been my experience that…The, the height of the high, vastly influences, the ensuing low…so it's important to try and be aware of the high, and not let it go out of control...trying to actively, sorry, proactively, not take on too much…And yeah, exercise and doing tai-chi or medication or something along those lines."*

Subthemes: The positive impact associated with changing physical activity levels

This section explores the connection between increasing PA levels and the perceived positive impact this can have on mood.

In terms of PA being an early warning sign for changes in mood, whether this was perceived to be before, after, or in tandem with the change in mood, several of the women interviewed went into great depth and passion when talking about the benefits from a type of personalised exercise support. Again, this provided the structure and controlled form of PA that allowed them to increase their PA levels and feel a positive impact on their mood:

Joanne*: "I know it helps me enormously having programmes to follow. Because I know when I get there I know what I'm doing, and even if it's really difficult…when I used to have personal training it was only once a month…I think if I didn't do that then I wouldn't still be going to the gym I'd have given up years ago"*

Sarah*: "I do a personal training session once a week which is, urm, and I do boxing. So again because it's quite physical the same as the running I know, if I use the weights and the machines and things like that it's fine, but I don't feel as good coming out of that so my PT session would be a half hour of boxing and a half hour of weight lifting. And partly because you've got someone there pushing you telling you what to do you work harder, you always try harder"*

Despite identifying the benefits of personal training, Sarah was cautious in making the link that exercise is beneficial to mood due to the worry that that would be perceived as exercise is the solution or cure to mental illness:

Sarah: *"I have been quite well for quite a lot of the time and I have managed to…reflect. And I'm quite self-aware…But I would never say to somebody else, 'have you tried…I mean one of the things that was good was when I was on the*

ward…they have a mini gym on the ward. So it had a treadmill. And I started because I'd went in very depressed…I was messing around with medication…used the treadmill as a way of walking…had that not been on the ward…I wouldn't have had the opportunity to think well that's helped…a little bit. I didn't say it out loud for ages."

Again, the evidence here could be suggestive that obtaining a balanced relationship between PA and mood is also dependant on other factors, such as medication, and there is an awareness that PA can be helpful for low mood, but that there are personal individual circumstances that need to feel balanced for this to have a positive impact. Throughout the discussed themes, participants seemed to need to feel ready and able to engage with PA before doing so. Knowing that PA might be helpful is not always enough to then engage with it, and if they do engage, other factors need to be controlled to have the right effect, if not, there is a perceived risk of making things worse.

Some participants went on to specify that a personal trainer with some knowledge of mental health could really help to overcome the negative impact low mood has on motivation and the energy and ability perceived by participants as necessary to undertake specific exercise, as well as being aware of when the exercise was too much, and potentially having a negative impact on high mood:

Jane: *"I've got a really good yoga teacher…to have someone, at least regularly monitoring how much I do, is really helpful. To kind of pull me back from the edge of the, yeah, from hurting myself...when I'm high, I've really got to have someone with me to monitor the amount I'm doing, the length of time I take, how far I push my body...to understand where they are in mood, how much exercise and what type of exercise to do to improve that mood, in whatever way that needs to be tinkered with."*

Abbie refers again to earlier comments she had made regarding limiting high intensity exercise, and adds that having someone to support and guide her with that

made her feel more comfortable and assured with the type of PA she was undertaking:

Abbie: *''You know, luckily, I got guidance from a PT, I got referred by the doctor for the gym, and he was, urm, not mental health trained…but I could speak to him and things, and he gave me an exercise programme that was literally fifteen minutes cardio and the rest was weights and things, so, you know, he really picked up on that''*

Overall participants felt that finding a type of PA that works for them, and keeps them balanced was very important, and there was shared acknowledgement that this would be different for different people, and potentially need to be altered in line with any presenting mood symptoms. Additionally, these quotes demonstrate a reflection that these changing needs in terms of PA and mood are early warning signs for PA having a negative impact with mood, further supported with the evidence from previously discussed themes of increasing and decreasing PA and SB levels, and the impact of PA and SB.

4.5.3 Findings summary

Key findings of this research are firstly that the relationship between PA, SB and mood is complex, multi-factorial, and dynamic. Secondly, people living with BD may feel in a constant state of trying to maintain balance in this relationship by juggling its various aspects, which becomes more challenging the more severe the symptoms/episode or influence of external factors. Thirdly, PA and SB can be both helpful and unhelpful for mood regulation, and there are individual, personal levels at which PA/SB can transition from being helpful, to unhelpful, and vice versa. For example, knowing that increasing PA when low in mood may be helpful is not always enough for a person living with BD to actively increase their PA, as this challenge is more complex than just the 'doing' of PA.

The identified connection between PA, SB, mood, and other influences such as volition, motivation, mood triggers (including environmental factors) and medication were perceived to contribute to the struggle to maintain a balance between PA and SB levels and mood. It also appears there is a difference between the PA and SB relationship with mood *symptoms*, and the relationship between PA and SB and a mood *episode*, in that mood symptoms when perceived to be mild can be balanced with PA and/or SB levels, whereas the quotes evidenced indicate this is more difficult to do for a full mood episode. This is due to a perception of being too unwell and not being able to engage in PA (when experiencing depression) and/or not being in control (when experiencing (hypo)mania).

Figure 4.9 below summarises the themes discussed throughout this study and illustrates their integration, outlining the identified and perceived complexities of the relationship between PA, SB and mood in BD.

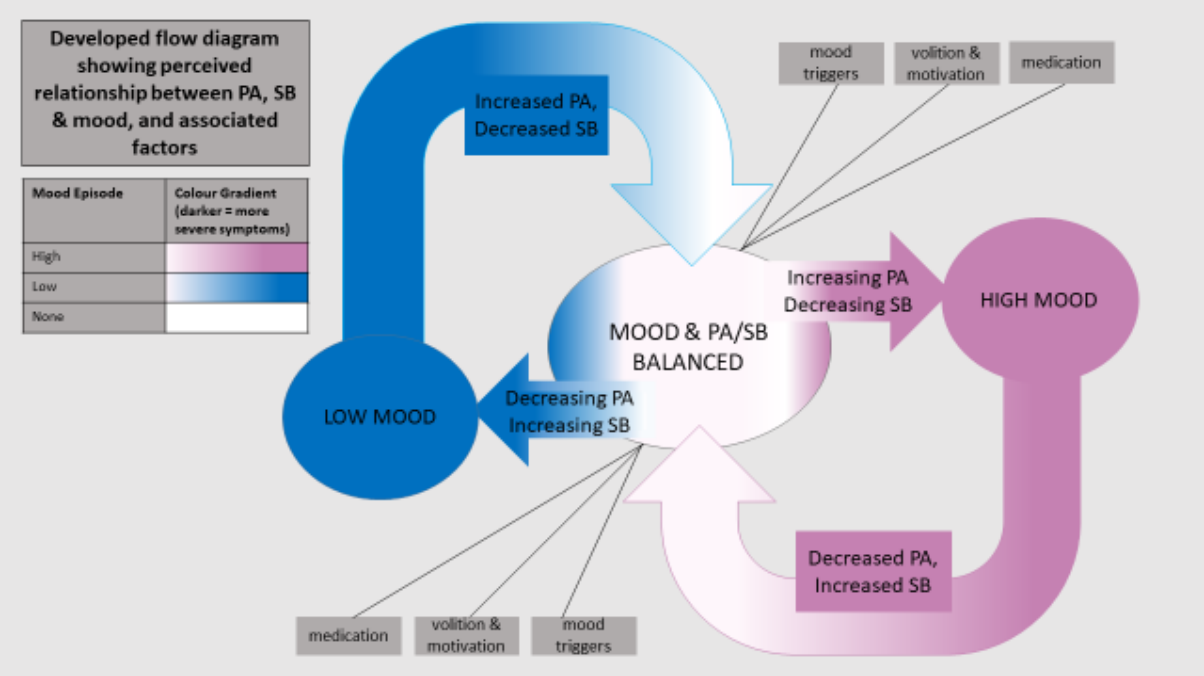


Figure 4.9 Flow diagram showing the perceived relationship between physical activity, sedentary behaviour, mood & associated factors

In Figure 4.9, the central area represents a balanced state of PA, SB, & mood. The arrows showing increases and decreases in PA or SB represent changing PA and SB levels, and how the changes moving away from a balanced state can be early warning signs for an impeding mood episode. The low and high mood areas show the negative impact changing PA/SB levels can have on an individual, resulting in imbalance. However, arrows leading away from a mood episode show how changing PA/SB levels at the right time can have a positive impact in helping someone regain balance. Motivation, volition, medication and mood triggers are factors identified as being embedded within this relationship which have the potential to influence any or all aspects of balance and imbalance in regard to PA, SB and mood. In summary, the diagram shows the integration of the main themes and subthemes of this study, particularly the key points where changing PA /SB levels were perceived to be related to mood, and where this change is perceived to be positive or negative.

4.6 Discussion

This section discusses the findings of this study, followed by the limitations and conclusions. A synthesis of the results from all three studies in this PhD is provided in chapter seven.

The over-arching theme of *'trying to maintain balance'* is comparable to the *'it's a double edged sword'* theme created by Wright *et al.*, (2012), identifying where exercise can be both helpful and unhelpful for mood regulation in people living with BD. Participant quotes from Wright et al., (2012)'s double edged sword theme, such as *''it is when I am at either extreme that it's [exercise] non beneficial - when I am particularly depressed or particularly high, when I'm at the spectrum in between, you know, mildly depressed or mildly hyper it can sometimes turn the mood''* demonstrate similar participant experiences as the current study. The current study has expanded on this and provided evidence of more than just exercise, such as routine and day-to-day PA, as well as SB. However, it is clear from examining the participant quotes that participants referred more to 'exercise' rather than PA, although considered some forms of PA such as walking, as exercise, despite the volition not being to keep fit and healthy. Furthermore, the clearest distinction made between PA and exercise was when participants referred to increased PA during experiences of high mood, however ceasing engagement with specific exercise usually carried out for the purposes of mood regulation.

Several participants within the current study suggested that a personal trainer with some knowledge of mental health could help to overcome internal and external struggles of motivation and the energy and ability perceived as necessary to undertake exercise, as well as being aware of when the exercise was too much, and

potentially having a negative impact on high mood. This was another finding echoed by participants in Wright et al., (2012), particularly in relation to the potential benefit of exercise regulation within exercise based interventions as a way of managing the relationship between PA and mood between mood states (i.e. depression and (hypo)mania). The participants in Wright et al., (2012) also referred to the benefits of routine for mood regulation, and issues relating to motivation, as in the current study. The current study therefore presents similar findings to Wright et al., (2012) and has built on this knowledge with experiences of PA as well as exercise.

Environmental factors appeared to have a role to play in the relationship between PA, SB and mood, and that potentially it is the integration of all these things alongside PA and SB that is important in relation to mood, rather than just PA/SB itself. This is supported by the findings of Vancampfort et al., (2017a) who found that meeting PA guidelines was associated with better quality of life across psychological, social, physical and environmental dimensions, concluding that there is a collective impact of these variables on engaging in sufficient, regular PA. This is also supported by Quirk et al., (2017) who describe an interplay of social, biological behavioural and psychological factors influencing the likelihood of engaging in PA, and maintaining that engagement. A possible explanation offered is that positive changes in health and fitness lead to an improvement in mental health, which increases engagement in activities (Vancampfort et al., 2017a) which can be considered in terms of an action-motivation cycle of change (Bundy, 2004) whereby doing more leads to wanting to do more as a result of multiple observed benefits, for example if increasing PA lead to improved physical fitness and psychological wellbeing. Environmental factors have been demonstrated to be complex and variable within and between individual experiences in this study, and attempts have

been made to understand these environmental factors in terms of barriers (to be addressed) and motivators (to be encouraged/ maintained) in the presentation of the findings.

Most previous research investigating barriers and facilitators for engaging in forms of PA (mostly exercise) in mental health populations have been quantitative in design (Soundy et al., 2014b; Busch et al., 2016; Firth et al., 2016a; Shor and Shalev, 2016; Sloan et al., 2018; Pereira, Padoan, Garcia, Patusco, & Magalhães, 2019) although only Pereira et al., (2019) discuss these specifically in people with BD. Further, only Wright *et al.*, (2012) explored perceptions of barriers and facilitators qualitatively in those with BD, and only in relation to specific exercise. This study identified similar barriers and facilitators to PA identified in this previous research, presented in Table 4.5, page 141. Most of these would also apply to the general population, e.g. the weather, time and access to facilities, however Table 4.5 presented some barriers and facilitators which can be considered specific to people with BD, which were discussed in the results. These included low mood as a barrier to PA, anxiety as a barrier to PA, high mood as a barrier to specific exercise, but simultaneous facilitator for general PA, and increased energy during high mood a facilitator for general PA. The important finding here is the little made distinction between exercise and general PA, and how high mood was considered a barrier only to specific exercise, which is reflective of the loss of structured activity which can be characteristic of (hypo)mania (APA,2013).

Pereira *et al.*, (2019)'s study which specifically explored barriers and facilitators for exercise engagement in patients with BD, unlike the current study, found that participants did not report knowing how exercise may 'positively influence' their illness. They did find however that the presence of symptoms was a significant

barrier to engagement with exercise, which supports the current study's findings, and also reported stigma as barrier. Whilst participants in this study did not refer to stigma in terms of exercise or PA engagement, there was a perceived barrier of anxiety identified. Participants described feeling concerned over the perceptions of others, for example worrying about how they looked, doing something wrong or not knowing what to do/ not being able to do something due to their mood. There was no evidence within this study to suggest this anxiety was a fear of stigma due to having BD, however this could be a result of cultural differences in acceptance and openness about BD as the Pereira *et al.*, (2019) study recruited inpatients in a Brazilian psychiatric hospital receiving treatment for BD, which may have impacted on their perceptions of stigma. Mason and Holt, (2012) also concluded in their review of qualitative literature in mental health and PA that participation in exercise interventions in particular felt socially inclusive and non-stigmatising to participants.

Participants in the current study described a relationship of doing less PA and lower mood, and of doing more PA and higher mood, and described these relationships within negative implications as the cycle was a constant struggle for balance that is difficult to maintain, with participants trying not to 'tip' into either mood state by juggling PA, SB and various other factors. One participant applied a 'self-feeding monster' metaphor to this relationship, implying the relationship is a negative force difficult to control. Illness metaphors have been a common area of interest in previous research both for physical and mental health conditions. Susan Sontag is arguably one of the early pioneers of challenging the 'illness metaphor' (Sontag, 1978), and much of her interpretations suggest patients feel ashamed of their illness, and use metaphors to assign a degree of negatively or even evil connotations to the illness, and that it would be healthier to accept the 'truth' of the illness. Kirmayer

(1992) argues that illness metaphors are required by people to make sense of their experiences and to communicate them, and Clow (2001) argues it is not possible nor necessarily appropriate to separate metaphors from illness perception, as they are an expression of what it feels like to someone, and arguably this cannot be accepted or rejected as a truth. The 'self-feeding monster' metaphor from the current study could reflect the participant's struggle to maintain a sense of control and balance, a concept supported by the quotes obtained from other participants who at times struggled to conceptualise what it was like to live with BD in terms of PA, SB, and mood regulation, only that this was challenging, and not a positive experience. Applying the term 'monster' highlights the perception that this is perceived as a negative rather than a positive connection. Schoeneman, Putnam, Rasmussen, Sparr and Beechem, (2012)'s study reviews a collection of illness metaphors specifically in BD, using a metaphor of BD as *'fire in the blood'* to headline their research paper. Again, the use of the word 'fire' implies a negative perception of BD and *'in the blood'* implies a lack of control or struggle to maintain control, mirroring the findings discussed in this study in relation to PA and SB engagement.

The only observable differences between BDI and BDII participants interviewed was that BDI participants seemed to suffer more from frustration and feelings of restlessness, and a need to be standing rather than sitting, with the sense that a busier day physically, was usually better mentally when feeling relatively stable, a finding not reported in previous qualitative literature. The women interviewed in this study also identified a fear of (hypo)mania, and becoming (hypo)manic, which none of the four men interviewed identified. Furthermore, the women in this study also reported finding routine PA and SB and structure beneficial for mood stability, whereas only one of the males interviewed described finding a routine helpful, and

this was due to a need to feel ‘kept busy,’ rather than for mood stability. Wright et al., (2012) was the most similar study to the current study both in terms of the study aim and results, however they did not report on demographic differences between participants. It is therefore difficult to compare this aspect of the results to previous research given the limited representation of BD in the literature, and the absence of any study qualitatively exploring the relationship between SB and mood in BD. Issues typically associated with older adults, such as physical health issues as a barrier and a motivator for specific exercise, were not only identified by the older adults in this study, but also by younger participants. However, as there were no other distinguishable differences found between the experiences of those with BDI and BDII, or males or females, and the interviews covered a broad age range of 31 to 72, it is reasonable to assume the findings of this research in relation to ‘trying to maintain balance’ would also resonate with others living with BD despite the lack of previous research to compare to in this area.

The current study has demonstrated a number of factors that were perceived to be playing a role in the relationship between PA, SB and mood which were explored as subthemes, including medication, mood triggers, volition and motivational issues. Intervention-based research aiming to encourage people living with BD to be more physically active, and/or engage in more exercise (Ashdown-Franks et al., 2018; Firth et al., 2018a; Masa-Font et al., 2015; McGinty et al., 2016; Vancampfort et al., 2015f; Yarborough et al., 2016) may benefit from considering the impact of these factors to improve the suitability of the intervention being offered, and its sustainability for self-management by participants long-term. For example, having a fitness instructor trained in mental health awareness, and the specific mood episodes characteristic of BD, may be helpful. If high mood is considered a barrier to

specific exercise, and if too much PA (particularly high intensity exercise) is considered a trigger for high mood, these could account for why some people living with BD feel unable to maintain a healthy balance between PA, SB and mood, as the balance requires more than just the regular engagement of PA. It has been acknowledged in previous research also that within mental health populations overall, other factors such as mood state, sustainability, suitability, and barriers and facilitators need to be considered in relation to PA (Chuang et al., 2008; Glowacki et al., 2017; Mishu et al., 2018; Vancampfort et al., 2013, 2017a) however not necessarily in BD, which is where the current study's findings are more novel and specific in regards to those living with BD.

4.6.1 Limitations

This study's participant sample was mostly characterised by females over 50 with BDI. Although this is demographically characteristic of the BDRN participants invited to take part in this study, it is not necessarily characteristic of the whole UK population of people living with BD. The average age was 57yrs old, and so the sample is arguably more representative of participants over 50 years old. This may however be due to participants who took part in this study having lived with BD for some time, as participants compared their perceived ability to manage their mood during early experiences of their illness, compared to present. For example, participants referred to being 'more aware' of their warning signs and triggers at interview than when they were first diagnosed or experiencing symptoms. Therefore, participants in this study may have had considerable time to reflect on their experiences relating to PA, SB and mood and/or being more comfortable talking about their experiences as they were already part of a research network exploring BD. This in itself is not a limitation, however may explain why most of the participants

who volunteered to be interviewed were of a certain age. Furthermore, previous research in this area (using either qualitative or quantitative methods) has been largely characterised by participants with BDI more than BDII (Janney et al., 2014; McGlinchey et al., 2014; Vancampfort et al., 2016a; Wright et al., 2012). BDI is arguably more easily diagnosed due to people with BDI presenting as inpatients more frequently (APA, 2013) due to the more severe episodes of mania they experience and being recruited for inpatient and intervention studies as a result. However, of the Wright et al. (2012) study which recruited 25 individuals with BD, only 3 of these had BDII, whereas the current study had 3/15 participants with BDII and so exhibits greater representation of the study sample to the experiences of BDII. Limited differences were identified between the experiences of BDI and BDII other than experiences solely of the mood symptoms part of the diagnostic criteria which distinguishes the illnesses. Therefore, it was not considered necessary to conduct targeted sampling to include more participants with BDII. Females have also been shown as more likely to volunteer in research than males (Ryan et al., 2019), and given than BDRN has more female participants overall, it is unsurprising that more females than males volunteered to take part, however Wright et al. (2012) recruited 10 male participants out of 25, and so showed greater representation of males than in the current study.

The study specifically aimed to explore PA including, but not limited to, exercise. This proved to be challenging as participants used the terms interchangeably, despite being asked about general PA, SB and specific exercise separately. This has been reflective of much of the previous research which was criticised in chapter two for not providing distinctions between PA and exercise. At the time of carrying out the interviews, it was considered by the researcher that providing prompts such as

‘by exercise, I mean something you do to keep fit and healthy’ and ‘by PA, I mean activities you do day-to-day that require movement’ was sufficient to encourage distinctions between terms without interrupting the flow of the conversation. On reflection, it may have been helpful to provide more precise definitions of PA and exercise, and SB and inactivity at the start of the interviews. However, it is possible that even in doing so, participants may have continued to use their own terminology instinctively, especially if they have always used terms interchangeably.

In the planning stage it was considered important to capture both experiences of exercise and day-to-day PA, as general PA and mood had not been explored qualitatively in BD, and there was limited research on experiences of exercise specifically in BD. It was also a consideration that the relationship between PA and mood may differ between that of structured exercise and mood, which was identified with the finding that high mood is a barrier to exercise but a motivator/facilitator for general PA. Although this study was the first known qualitative exploration of experiences of SB and mood in people living with BD, on reflection the topic guide was still more focused on identifying experiences of PA and exercise, rather than SB, and more prompts could have been used to identify any experiences of SB in relation to mood. The relationships between SB and mood were more subtle in the interviews, and were described in terms of the domain, e.g., ‘watching television,’ or ‘sitting quietly.’

The data analysis stage identified data that widely related to experiences of mood disturbance and of living with BD, but not to the study aim of relationships between PA, SB, and mood. The topic guide began with an open question about experiences of high and low mood. This was included to try to ease participants into the interview by encouraging them to talk about what high mood and low mood is like for them

personally. On reflection, this approach may have contributed to more data being collected which did not relate to the study aim. Although this information was interesting and helpful for considering the personal wider impact of mood in BD, it was not necessarily required data. Furthermore, although it was acknowledged that the focus on mood at the beginning of the interview may explain why there were data non-related to the study aim, it was considered a good topic to begin the interview with by allowing opportunity to build rapport with the participants by asking them more broadly about what it is personally like for them to live with BD, and so no amendments were made to the topic guide throughout data collection. The interviews were carried out in a relatively short period of time due to the availability and geographical location of the participants, and so it was not possible to transcribe every interview before conducting the next one. However, if each interview had been transcribed prior to the next this may have allowed more opportunity for reflection on the suitability of the topic guide, and for the topic guide to be amended accordingly as interviewing progressed to incorporate any emergent ideas or concepts.

4.6.2 Conclusions

This study was the first to qualitatively explore relationships between PA, SB, and mood in people with BD. Although participants talked about PA and their perceptions of exercise more than SB, there were a number of findings from this study which provide evidence of a perceived relationship between SB and mood. For example, it was identified that SB can be helpful for mood regulation when experiencing high mood, and can be a useful way to relax and focus on a non-physically active activity to prevent or manage a high mood episode. This study presented an over-arching theme of trying to maintain balance, something participants struggled to maintain due to changing PA and SB levels, and positive and negative impacts of PA and SB,

with PA and SB also being early warning signs that mood is potentially changed or about to change. This study also identified that the relationship between PA, SB, and mood is perceived as complex and multi-factorial, and is related to other factors such as medication, mood triggers, volition, and motivation.

5 Chapter Five: Relationships between device-measured physical activity, sedentary behaviour, & bipolar disorder mood symptoms

5.1 Introduction

Chapter five continues the exploration of relationships between physical activity (PA), sedentary behaviour (SB) and bipolar disorder (BD) mood symptoms using device-measured PA and SB, alongside self-reported BD mood symptoms, to statistically examine these relationships; whilst considering possible confounding factors in any identified relationships. Potential factors that may potentially confound any relationship between PA, SB and mood were identified from previous research (Vancampfort et al. 2013) (discussed in Chapter two) and from the findings of study one (Chapter four), and included gender, age, medication, BMI, physical health comorbidities and psychiatric history.

Study one (Chapter four) also identified a complexity in the relationships between PA, SB and mood symptoms, with participants identifying that there was a constant struggle to try to maintain balance between PA, SB, and mood. Any changes to PA or SB were perceived as positive or negative depending on the overall impact on general wellbeing (physical and mental health). There was agreement across participant interviews that there were relationships between PA, SB, and mood, however, there was not clear agreement regarding exactly what these relationships are or how strong they are, and so this study provided an opportunity to identify the statistical strength and direction of relationships between PA, SB and BD mood symptoms using a strong device-based measure of PA and SB.

This study also provided opportunity to explore specific mood symptoms identified in study one (Chapter four) as being perceived to be related to PA and SB changes; including (but not limited to) ‘anger,’ and feeling ‘energetic,’ to contribute to the overall research question of ‘what are the relationships between PA, SB and BD mood symptoms?’

As evidenced in the literature review (Chapter two), there is no published research to date specifically investigating relationships between SB and mood symptoms in BD, or indeed much research exploring SB in BD at all, using an appropriate device-based measure of SB, such as the ActivPAL3 activity monitor (see Table 2.3, page 40). Given the previously identified limitations of self-report measures for estimating SB, and the known links between SB and depression (Stubbs et al., 2018b; Teychenne et al., 2010; Vancampfort et al., 2018b; Zhai et al., 2015), further investigation into SB and mood specifically in BD using a device-based measure of SB is warranted, as people with BD experience both depressive and (hypo)manic mood symptoms, and the relationships between SB and (hypo)mania are unknown. Furthermore, although there was some validity identified for the use of the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) as a self-report PA tool in people living with BD (see chapter two, page 33: Vancampfort *et al.*, 2016e), there is, to date, no validated or recommended SB tool specifically in people living with BD. The MSQ was identified in chapter two (page 37) as being a potentially suitable measure which warranted further exploration as part of this study.

In sum, although relationships between PA and mood have been partially explored in previous research, the relationships between PA, SB and mood symptoms have yet to be explored specifically in people living with BD using appropriate, device-based measurements of both PA and SB.

5.2 Aims & objectives

Aim 1: To explore the relationships between device-measured PA, SB and self-reported depressive and (hypo)manic mood symptoms in people living with BD.

Objective 1: To quantify and report daily and weekly PA and SB in people living with BD using the ActivPAL3 activity monitor.

Objective 2: To gather self-reported daily (Mood Zoom: anxiety, elation, sadness, anger, irritable, energetic) (MZ) and weekly depressive (Quick Inventory of Depressive Symptoms) (QIDS) and (hypo)manic (Altman Self Rating Mania Scale) (ASRM) mood symptoms in people living with BD.

Objective 3: To explore the relationships between device-measured daily PA, SB, and self-reported BD mood symptoms (MZ) over a 7-day period.

Objective 4: To explore the relationships between device-measured weekly totals of PA, SB, and self-reported 7-day recall depressive (QIDS) and (hypo)manic (ASRM) BD mood symptoms.

Objective 5: To identify potential confounding factors in the relationships between device-measured PA, SB, and self-reported BD mood symptoms.

Aim 2: To explore the validity of the Marshall Sitting Questionnaire (MSQ) (Marshall et al. 2010) for use as a self-report 7-day recall tool for calculating SB from time spent sitting in people living with BD.

Objective 1: To calculate weekday, weekend day, average day and total week self-reported sitting time and report on the sitting behaviours of people living with BD using the MSQ.

Objective 2: To explore the validity of the MSQ as a self-report 7-day recall tool in BD by comparing weekday, weekend-day, average day, and total week self-reported sitting time against device-measured weekday, weekend-day, average day, and total week time spent in SB from an ActivPAL3.

Objective 3: To compare the relationships between self-reported 7-day recall total week sitting time (MSQ) and self-reported 7-day recall mood, to those found using device-measured SB from an ActivPAL3.

5.3 Method

5.3.1 Participants

5.3.1.1 Sample size

BDRN have had previous success using wearable activity monitors (Actiwatch: actigraph.corp) with a small subset of participants (N=10 completed study, N=7 usable data sets); (Swaden-Lewis, 2017). Other studies using activity monitors in people living with BD have demonstrated varying sample sizes of three to sixty (see Chapter two, Table 2.4, page 50). Terwee *et al.*, (2010) recommends a minimum of 50 participants to validate self-report PA/SB questionnaires against device-based measures. Given Aim 2 of this study, a target sample size of 50 participants was set, with a minimum of 30 participants being required to carry out meaningful analysis above what had already been published in the Vancampfort *et al.*, (2016) study which attempted to validate the IPAQ.

5.3.1.2 Inclusion & exclusion criteria

Chapter three previously outlined the BDRN recruitment process, as well as the general inclusion/exclusion criteria, ethical considerations and recruitment process used for this PhD. In addition, potential participants for this study were not eligible to take part if they had had a reaction to a plaster or similar medical dressing in the past, as the ActivPAL3 was adhered using a waterproof dressing. This information was in the participant information leaflet (appendix J) and participants were asked during the participant screening process (Chapter three, page 97) if they had had any reactions to medical dressings in the past. In addition, potential participants who were unable to walk and required use of a wheelchair were unable to take part as the ActivPAL3 would show a predominant state of SB due to posture orientation.

This exclusion criteria was made in line with previous research (Clemes et al., 2012; Ostendorf et al., 2018; Sasaki et al., 2019).

5.3.1.3 Study invitation & information leaflet

The study invitation was an email (appendix J) inviting potentially eligible participants to take part in an 'activity and mood monitoring study.' The email asked interested participants to respond to the email with a contact telephone number. The information leaflet (appendix J) briefly described the purpose of the study and what taking part entailed, and advised participants of the eligibility criteria. This was an attachment to the study invitation email.

5.3.1.4 Recruitment process

Participants were contacted via email in small numbers to avoid being overwhelmed with participant interest and not having enough ActivPAL3s (N=7) to fulfil this interest. For example, the first potential participants to be individually contacted comprised of those who had been interviewed in study one (chapter four), as they had already received information on this study (study two) following their interview. Of these participants, 12/15 who had been interviewed responded to the invitation to take part in this study. Eleven participants volunteered to take part, and one declined due to becoming unwell since being interviewed.

All contacted participants received a reminder email two weeks after the initial email invitation went out. Total recruitment figures are outlined below in Figure 5.1.

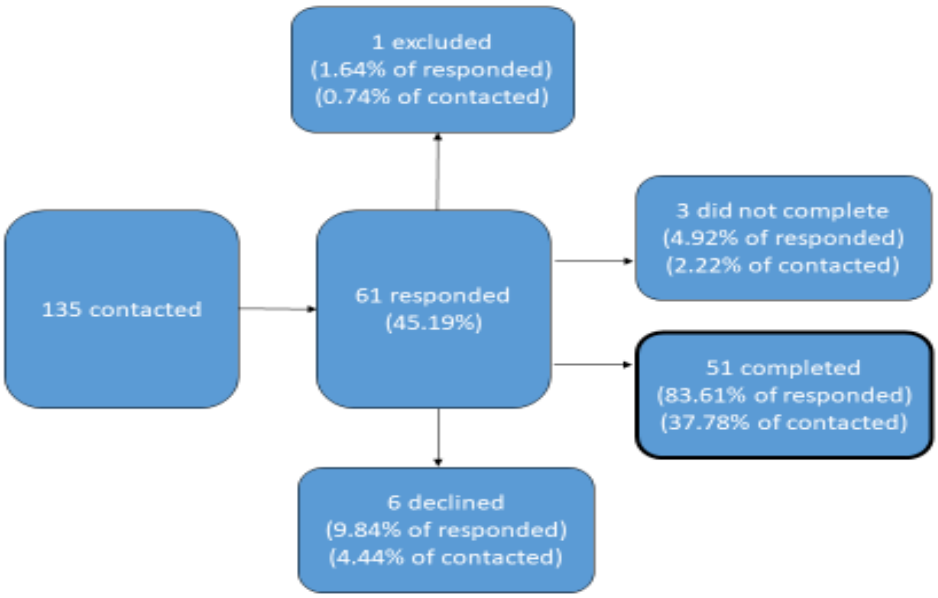


Figure 5.1 Study two recruitment flow chart

Figure 5.1 shows that 45% of potential participants contacted about this study responded to either volunteer to take part, or to decline the research invitation. Three people declined due to personal circumstances, e.g., starting a new job; two declined due to being unwell in mood at the time of recruitment; one declined due to not wanting to wear the ActivPAL3, and one was excluded due to being allergic to adhesive dressings. Figure 5.1 also shows that of those who responded, 84% went on to complete the study, and three people who volunteered did not complete: one was due to two failed recordings from the ActivPAL3; one due to not being able to contact the participant to arrange delivery of the ActivPAL3; and one due to experiencing problems with applying the waterproof dressing.

5.3.2 Measures

5.3.2.1 The ActivPAL3

The ActivPAL3 is a small, lightweight (weight: 10g dimensions: 23.5mmx 43mmx 5mm) activity monitor capable of distinguishing between upright and sitting/lying activities, developed and manufactured by Physical Activity Levels (PAL) Technologies (palt.com). The device should be worn on the front upper thigh in a nitrile sleeve, attached to the skin using a waterproof dressing (Tegaderm™) so that it does not need to be removed for showering or bathing (see Figure 5.2 below).

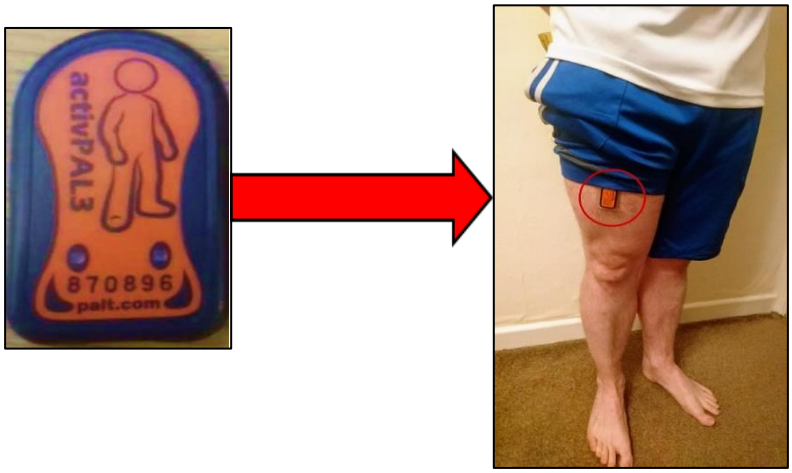


Figure 5.2 ActivPAL3 device & placement (personal photographs)

The ActivPAL3 provides 'free living' PA and SB calculations by recording posture orientation via the position and movement of a person's lower limb, and measures acceleration at a sampling frequency of 20hz which is used to calculate activity 'events' (e.g. sitting/lying, standing and stepping: min. sitting/lying period is 10secs, and min. upright period is 10secs). PAL Technologies (palt.com) uses classifications from the World Health Organisation (WHO,1985) and James (1990) to assign MET values (metabolic equivalent of task) to activity 'events' calculated by the ActivPAL3: sedentary (e.g. sitting, lying, reclining) =1.25METs; standing (e.g. stationary but

upright) =1.4METs; and stepping (e.g. walking) =4METs (at a cadence of 120 steps per minute). Stepping cadence (at 4METs) can then be used to classify stepping activity into light PA, or MVPA.

5.3.2.2 Activity & mood monitoring study pack

The activity and mood monitoring study pack (see appendix L) collected various data required throughout the duration of the study. One BDRN staff member and two students at the University of Worcester agreed to pilot the study pack whilst wearing the ActivPAL3 and fed back on the study pack's presentation and ease of use. Following this feedback, the study pack underwent several revisions to improve the presentation and ease of completion with the support of the BDRN research team before being submitted for ethical approval (see Chapter three page 96).

The first page of the study pack provided general instructions and guidance for the study and opportunity to self-report current weight, height and medication use, followed by a 7-day (1 page per day) pre-dated sleep and mood-monitoring log. Three self-report 7-day recall questionnaires followed. The pack concluded with a reminder to post the ActivPAL3 and pack contents back to the researcher at the end of the 7-day period. The contents of the study pack are described below:

5.3.2.2.1 The daily sleep & device removal log

On each of the 7-days in the sleep and device removal log, participants were asked to detail times of sleep for the night before (in the morning upon waking), and any naps taken or removal of their device that day (in the evening before bed) to assist the researcher in identifying sleep and non-wear time as this can affect the quality and accuracy of data produced by the ActivPAL3 (Edwardson et al., 2015). This took

approximately 2mins a day to complete when tested (approximately a minute in the morning and a minute in the evening).

5.3.2.2.2 Daily mood

For each of the 7-days, daily mood symptom severity was self-reported by participants using a paper adaption of the Mood Zoom (MZ) mobile application (Tsanas et al., 2016) which measures symptom severity across six items *(anxious, elated, sad, angry, irritable, energetic)* on a seven point scale (1-7). Participants were asked to log their mood for that day every evening before going to bed (taking approximately three minutes to complete when tested).

5.3.2.2.3 Weekly mood

Two short self-report 7-day recall mood questionnaires were completed on the last day (day 7) of the 7-day period: The Quick Inventory of Depressive Symptoms (QIDS) (Rush et al., 2003), (16-items) determined the presence and severity of depressive symptoms for the 7-day period; and the Altman Self Rating Mania Scale (ASRM) (Altman et al., 1997) (five items) determined the presence and severity of (hypo)mania symptoms for the 7-day period. Each questionnaire took approximately 5mins to complete when tested.

5.3.2.2.4 The Marshall Sitting Questionnaire

The Marshall Sitting Questionnaire (MSQ) (Marshall et al., 2010) (5-item) was completed on the last day (day-7) of the study to gain domain related data for sitting times (hours/minutes) across weekday and weekend days, and to provide a self-report measure of SB to compare against the ActivPAL3 and establish levels of agreement. The MSQ took approximately 5mins to complete when tested.

5.3.3 Procedure

The procedure for study two is presented in Figure 5.3 below.

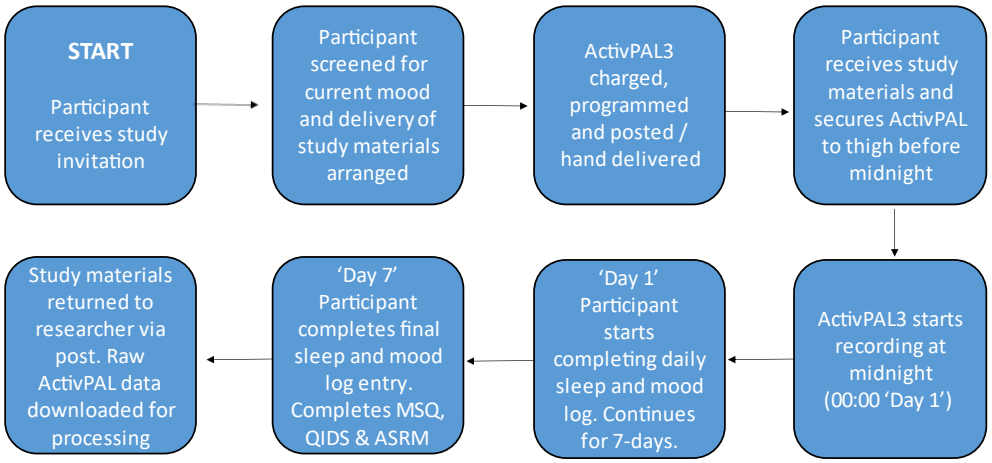


Figure 5.3 Study two procedure flow chart

Data collection occurred between August 2018 and April 2019. Participants who responded to the invitation email to say they were interested in taking part were contacted via telephone and screened to establish current mood state and eligibility (Chapter three, page 97) prior to arranging delivery of the study materials. Three participants were experiencing significant mood symptoms during the screening and so participation was postponed for a minimum of two weeks, after which another mood screening was carried out. Participants were offered a home-visit, or to have the materials posted to them via special delivery.

Twelve participants chose a home-visit and were encouraged to secure the ActivPAL3 using the waterproof dressing whilst the researcher was present, so that

the researcher could assist if necessary. This also ensured the participant did not forget to apply the ActivPAL3 before it started recording.

Thirty-nine participants opted for postal delivery and received the study materials on an agreed day via Royal Mail Special Delivery (guaranteed before 1.00pm, or at the request of the participant if they were going out, 9.00am) then received a follow up phone call to ensure they had received the materials, and to answer any questions after reviewing these. Following recommendations made by Edwardson et al., (2015) on using the ActivPAL3 in research, participants received instructions (appendix K) on where to place the ActivPAL3, how to adhere it to the skin using the nitrile sleeve and waterproof dressing provided (Tegaderm™) and when to change the dressing. These instructions were formed from guidance given by the manufacturer (palt.com) at the time of ethical approval (see page 96). Attached to the instructions was a pouch containing 5x nitrile sleeves and adhesive waterproof dressings (Tegaderm™).

The night before posting/hand delivery, the ActivPAL3 was fully charged using a docking station and then programmed in PAL Technologies software (PALConnect-V7, palt.com) to record posture orientation for 9-days, with the recording starting at midnight on the evening the participant received the device. The ActivPAL3 was set to record for 9-days in case there was a delay in the participant receiving or applying the device, (e.g. if they missed the agreed delivery slot and had to collect the package from the delivery office the next day the study pack dates could be adjusted to allow the participant to continue with the study and still provide 7-days of data).

For each day of the study, starting with ‘day 1’ up to ‘day 7’ in the study pack, all participants were asked to complete the daily sleep log every morning for the night

before, and other aspects relating to naps and any removal of the device every evening before bed each day for the duration of the study. Participants were also asked to complete the daily mood log (MZ) every evening before bed for the duration of the study.

The ActivPAL3 was continuously worn for 7-consecutive days from the day of delivery unless the participant removed the device for any reason, such as to change the waterproof dressing, which was to be done every 2/3 days for hygiene purposes and to prevent any skin irritation. The researcher was available via email, text and telephone to support participants with any queries or concerns during this time, e.g. if the ActivPAL3 stopped intermittently flashing a green light it meant the recording had failed, participants were advised to contact the researcher if this happened (see Appendix K) and a new ActivPAL3 and study pack was sent out. This happened on three occasions when the ActivPAL stopped recording early in the 7-day period (day 1 or 2). However, not all participants notified the researcher of a device or battery failure, as 7 participants returned their ActivPAL3s and study packs with less than 7-days data from the ActivPAL3. On the afternoon of the last day (‘day 7’) participants received a phone call from the researcher to remind them to complete the three self-report 7-day recall questionnaires that evening (QIDS, ASRM and MSQ); to remove the ActivPAL3 before going to bed; and to post the study pack and ActivPAL3 back using the pre-stamped returns envelope provided, which included a protective pouch for the ActivPAL3.

Upon return the raw ActivPAL3 data were downloaded into PAL Technologies software (PALanalysis-V7, palt.com). A thank you letter and a copy of the ‘day by hour’ summary report generated from this software (see Figure 5.4 below) was

posted to each participant, with information and guidance on how to interpret this report (see appendix N).

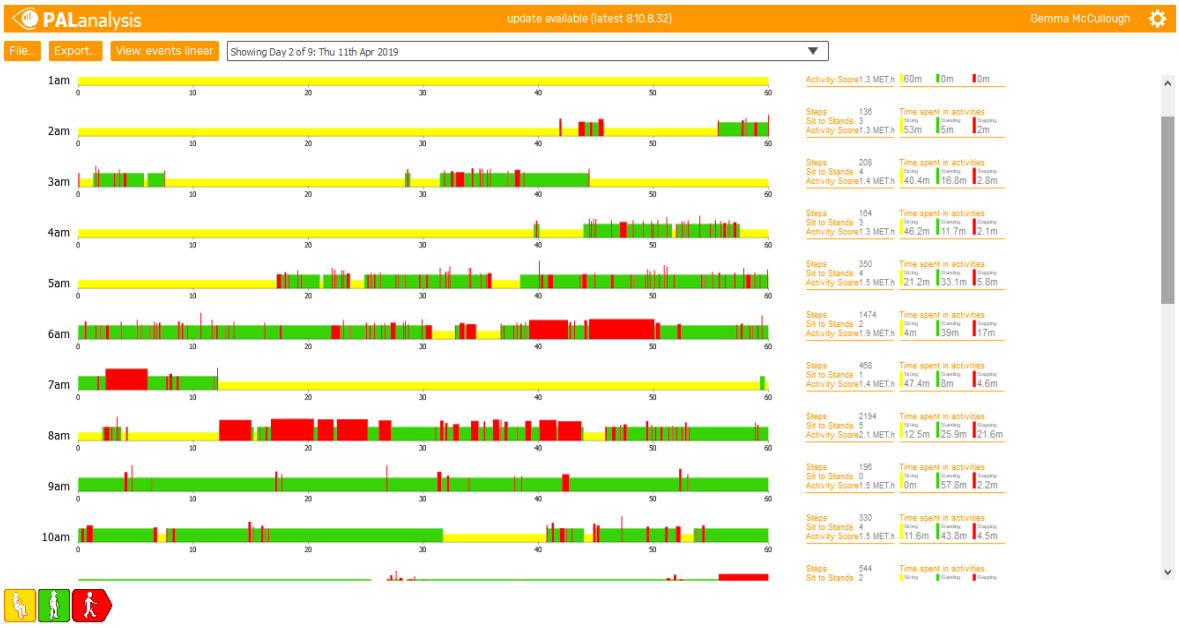


Figure 5.4 Copy of day-by-hour ActivPAL3 summary report sent to participants on completion of study. Yellow represents time spent sitting/lying (including sleep). Green represents time spent standing & red represents time spent stepping/walking

5.4 Data handling, cleaning & assumptions

This section outlines the steps taken to prepare, check, and process the various data collected, and why the approaches taken for data preparation were required. This section also reports on analysis preparations (such as checking if parametric assumptions were met) and inclusion and exclusion criteria for analysis.

Physical activity & sedentary behaviour data: ActivPAL3

The raw data from the ActivPAL3 were downloaded from the device when connected to the PAL Technologies software (PALanalysisV-7, palt.com). The data were visually inspected (see Figure 5.4 above) following the application of the 'Automated Vane Algorithm' built into the more recently available PAL software update (PALanalysis-V8, palt.com) which highlighted invalid recording days (for example if the recording had failed at any stage or if the battery had died) and produced daily summaries and average day summaries of some PA and SB variables, such as time spent sitting, standing and stepping, but not accounting for sleep or non-wear time, or classifying PA intensity.

To reliably remove sleep and non-wear time and then calculate a number of PA and SB variables for analysis, such as time spent in moderate to vigorous intensity PA (MVPA), the raw ActivPAL3 data (original event files) were then processed in STATA (STATA-15, stata.com) statistical analysis software using pre-written code for a validated algorithm. This algorithm was developed by Winkler et al., (2016) and validated using participants who were considered obese, and engagaing in high levels of SB to determine thresholds of sleep and non-wear in the algorithum. The STATA code for the algorithum was obtained during a training course on 'processing objective measures data' at the University of Leicester in May 2017 hosted by one of

the co-authors. This code was used as opposed to others introduced during the training course that used specific time windows of waking wear, or restricted sleep times from general population data, as it assumed a 24hr wear protocol, and had a lower threshold of waking hours required (10hrs). Some studies have recommended the use of greater waking wear time requirements, e.g. 13hrs (Patel et al. 2006) however this is questionable in populations that may exhibit greater durations of sleep or disrupted sleep, such as those experiencing depression (Nivoli et al., 2011; Lopresti, Hood and Drummond, 2013; Sarris et al., 2014; Gonzalez et al., 2018). Therefore, increasing the waking wear requirements for a valid day was not considered appropriate for BD as it would exclude the data of those with shorter waking wear durations. Furthermore, the MSQ validation study (Marshall et al. 2010) also applied a waking wear rule of 10hrs in their sample, citing the advice of Trost et al. (2005)'s paper on using accelerometers in field research as support of its use, and found that they unnecessarily lost a considerable number of otherwise valid days when they extended this to 14hrs.

The algorithm used applies no restriction in terms of maximum waking wear time (i.e. no sleep has to be identified within a 24/h period to constitute a valid day). The algorithm was therefore applied using its recommended thresholds which considered a day to be invalid if it had <10hrs of waking wear time, <500 steps, and/or any one activity that made up ≥95% of waking wear time (Winkler et al., 2016). After applying this code it was identified that of the 51 participants, 44 had 7-valid days of ActivPAL3 data, 4 had 6-valid days, 2 had 5-valid days, and 1 participant only had 3-valid days. These invalid days identified by the algorithm consisted of days where the ActivPAL3 recording had ended prematurely due to a battery failure or technical fault with the monitor, or if the monitor was removed prematurely on the final day of

the study (day-7) by the participant which resulted in more non-wear than wear time for the 24/h. As the ActivPAL3 was set to record for 9-days as a precautionary measure in case there was a delay in the participant receiving the device, days 8 and 9 mostly showed as invalid due to the battery dying or any or all of the above thresholds being met. Two participants however were a day late in receiving or applying their ActivPAL3 and so in these cases, day-1 was invalid, however day-8 on the recording was valid, still producing 7-days wear.

A pre-written STATA algorithm code (using the now processed event files) which was also obtained from the 'processing objective measures' training course was used to create the below activity variables for analysis. The code counts the number of occurrences (events) of an activity (0=sedentary, 1=standing, 2=stepping) to determine the sum duration of the activity per valid day.

The code creates the following variables for each 'valid' day of ActivPAL3 data for each participant.

- Time spent in SB (hrs)
- Time spent standing (hrs)
- Time spent stepping/walking (hrs)
- Number of steps taken
- Time spent in light intensity PA (hrs)
- Time spent in moderate/vigorous PA (MVPA) (hrs)
- Number of SB to upright transitions
- Number of SB bouts
- Number of SB bouts lasting 0-30mins
- Time spent (hrs) in SB bouts lasting 0-30mins
- Number of SB bouts lasting 30-60mins
- Time spent (hrs) in SB bouts lasting 30-60min
- Number of SB bouts lasting 60-120mins
- Time spent in SB bouts lasting 60-120mins
- Number of SB bouts lasting over 120mins
- Time spent in SB bouts lasting over 120mins
- Daily averages for the recorded period for all of the above variables

The sum of each variable for each day in the above list was then calculated using a formula in excel to produce weekly totals of each variable (except daily averages).

All of the above variables (daily averages and weekly totals) were explored to assess whether these showed a normal data distribution, and whether parametric assumptions were met using the explore function in IBM-SPSS-24 (ibm.com).

All variables except the number of bouts lasting over 120mins, and time spent in bouts lasting over 120mins (hrs), met parametric assumptions and were considered normally distributed: the p-values on the normality tests were greater than 0.05, (Kolmogorov-Smirnov and Shapiro-Wilk) the means and medians were close, and the standard deviations were less than the means. The histograms did not show a definite bell curve for all variables, and some points fell off the lines of the normality plots, although this was moderate given the relatively small sample size.

Finally, a *'day type'* variable (weekday or weekend day) was created using the date stamp on the ActivPAL3 data in excel. *'Time spent in SB'* was then totalled and averaged using excel for both weekdays (total time spent in SB/number of valid weekdays) and weekend days (total time spent in SB/number of valid weekend days) to use when comparing weekday and weekend day ActivPAL3 data to the self-reported MSQ responses.

ActivPAL3 data inclusion & exclusion criteria

The processed ActivPAL3 data variable for 'number of valid days' was used to determine the inclusion or exclusion of particular days or whole recordings of ActivPAL3 wear for the analysis.

Various recommendations have been made on how many valid days are required to complete weekly analysis using activity monitor data. Sasaki, Motl and McAuley, (2019) included participants who had at least 2 valid days of data that includes at least one weekend day, whereas Trost et al., (2005) advise 3-5 valid days be included to reliably estimate habitual PA and SB. The MSQ validation paper (Marshall et al. 2010) included data with 5-valid days of recording, one of which had to be a weekend day.

For the participant that only had 3-valid days of data in the current study, these were all weekdays and so both weekend days were invalid. This participant was therefore excluded from analysis concerning the agreement between the ActivPAL3 and MSQ weekend-day data. For all other participants (N=50) there were at least 5 days of valid ActivPAL3 data including at least 1 weekend day, and so they were all included in analysis concerning ActivPAL3 data and agreement between ActivPAL3 SB time and the MSQ (except where participants were excluded due to missing/invalid MSQ responses, see pages 204-206).

The daily sleep & device removal log

There is no gold standard or accepted procedure reported in the literature on using sleep log data in relation to device-based measurements of PA or SB. However, it is widely acknowledged that sleep logs are useful for visual inspections of activity monitor data to distinguish between time spent in SB, and sleep (Edwardson et al., 2015; McVeigh et al., 2016; Van der Berg et al., 2016; Winkler et al., 2016; Ostendorf et al., 2018) and manually correcting data from device-based measures that was misinterpreted in automated algorithms as sleep, if it was actually SB, and vice versa, if required. Time spent asleep is not SB (Tremblay *et al.*, 2017;

SBRN.com) and so knowing if someone went to bed but was awake for an hour before falling asleep for example, was again important for determining accurate SB time from the ActivPAL3.

As the ActivPAL3 does not automatically identify sleep and non-wear time in the PAL Technologies software (PALanalysisV-7, V8, palt.com) and an automated algorithm was used to remove sleep and non-wear time (Winkler et al., 2016), the sleep log was used to calculate sleep duration per 24/h period for each participant. This was done by comparing the reported 'time fell asleep' from the sleep log with the 'day by hour summary report' (see Figure 5.4 above) (PAL-analysisV7, palt.com) to visually inspect whether this sleep time was likely accurate, for example, the participant was not still stepping when reported being asleep in the log. As the sleep log did not ask for time 'got out of bed,' in the morning, sleep time was estimated for each 24/h period as follows, using an online time difference calculator (www.timeanddate.com):

- 00:00 to time of first significant movement.

  +

- Time of reported 'time fell asleep' to 00:00

  +

- Reported times of any naps

Solid blocks of standing (shown in green) were still considered sleep if it was not broken up by steps (shown in red) as this was most likely an elevated leg causing the ActivPAL3 to record posture as standing whilst asleep (Edwardson et al., 2015; Winkler et al., 2016).

The sleep logs' 'times device removed' showed short removal periods of the ActivPAL3 of typically less than 5mins in duration to change the waterproof dressing,

if at all, and so the decision was made not to investigate self-reported non-wear time further.

This process identified that the automated algorithm had worked well in removing sleep and non-wear time as there were no concerning anomalies between the sleep time reported by participants, and the SB blocks shown on the ActivPAL3 ‘day by hour’ summary reports. It is important to remember that this process is an estimation only of sleep time by combining self-reported sleep and visual inspections of the data to provide a best estimate of SB time with sleep time removed. An additional check was carried out to explore how well the algorithm had removed sleep time from time spent in SB: the sleep time per person (per 24/h period) was deducted from the initial reporting of time spent in SB from the ActivPAL3 (PALanalysisV-8, palt.com) using an excel formula. This left the most reliable possible estimate of time spent in SB. Supplementary information on the limits of agreement between the two methods (sleep time removal using manual sleep log calculations v the algorithm) are provided in Appendix O.

The daily mood log: Mood Zoom

Each of the five MZ items were treated independently. There is no total score for each daily completion of MZ, as each item measures a different feature of mood. As MZ is ratings data, the items were also averaged for the 7-day period using the median function in excel for the purpose of describing the range and average scores of the participant sample. All MZ items were checked using the explore function of IBM-SPSS-24 (ibm.com) statistical software to ensure all responses fell within the possible range (1-7).

The Quick Inventory of Depressive Symptoms

The highest score from each of the nine domains that make up the 16-items of the QIDS was summed to provide the total score. The maximum score possible is 27. Scores were totalled by hand on the questionnaire, and then double-checked for accuracy. All QIDS items and total scores were required for analysis and were checked using the explore function of IBM-SPSS-24 (ibm.com) to ensure all responses fell within the possible ranges (QIDS: items=0-3, total=0-27).

The Altman Self-rating Mania Scale

The sum of the 5-items of the ASRM provided a total score. The maximum score possible is 20. Scores were totalled by hand on the questionnaire, and then also double checked for accuracy. All ASRM items and total scores were required for analysis, and were checked using the explore function of IBM-SPSS-24 (ibm.com) to ensure all responses fell within the possible ranges (ASRM: items=0-4, total=0-20).

Mood state

Although the total scores of the QIDS and ASRM provide a more statistically sensitive approach to analysis, the questionnaires were initially designed to screen for an episode of depression (QIDS) and (hypo)mania (ASRM) and its severity using cut off values from the total score. These were used to describe the mood state of the current study's participant sample to identify how many people, if any, may have met the criteria for a mood episode during their participation.

On the QIDS, a score of 0-5 indicates no depression, 6-10 indicates mild depression, 11-15 indicates moderate depression, 16-20 indicates severe depression, and 21-27

indicates very severe depression for the 7-day period (Rush et al., 2003). On the ASRM, a score of 5 or higher indicates a (hypo)manic mood state for the 7-day period (Altman et al., 1997).

A variable was created to describe the mood state of the participant sample for the 7-day period as either euthymic, depressed, (hypo)manic, or in a mixed state (experiencing (hypo)mania and depression).

As a score of 5 or less on the QIDS and a score of 4 or less on the ASRM indicated no significant mood symptoms, these participants were coded as *'euthymic'*. As a score of 5 or less on the QIDS, but 5 or more on the ASRM indicated (hypo)mania, these participants were coded as *'(hypo)manic'*. As a score of 6 or more on the QIDS but 4 or less on the ASRM indicated depression, but no (hypo)mania, these participants were coded in relation to the level of depression indicated by their QIDS score *('mild'/'moderate'/'severe'/'very severe')*. As a score of 6 or more on the QIDS indicated a level of depression, and a score of 5 or more on the ASRM also indicated (hypo)mania, these participants were coded as *'mixed state.'*

Only the total QIDS and ASRM scores were used in any statistical analysis, (i.e. not the categorical approach). The purpose of determining mood state and assigning participants to mood categories was to describe the mood state of the participant sample only.

The Marshall Sitting Questionnaire

Average weekday sitting time was calculated for each participant by first converting each of the five MSQ items from hours and minutes into hours only using an excel formula. The sum of the five-items then provided the total time spent sitting (hrs) on

an average weekday for the 7-day study period. This process was repeated for the five weekend-day MSQ items to provide total time spent sitting (hrs) on an average weekend-day for the 7-day period. Hours was chosen as the unit of measurement instead of minutes to make the data comparable to the ActivPAL3 variable of 'time spent in SB (hrs)' for carrying out the analysis to test the agreement between the MSQ and ActivPAL3, and to make the weekly total scores more meaningful.

Total self-reported sitting time for the week was estimated by calculating the following in excel: (weekday total sitting time_hrs x5) + (weekend day total sitting time_hrs x2). This total was then divided by 7 to provide the 'average day' sitting time.

All of the MSQ variables were explored to assess whether these showed a normal data distribution, and whether parametric assumptions were met using the explore function in IBM-SPSS-24 (ibm.com).

The individual weekday and weekend domains were not normally distributed and did not meet parametric assumptions. Although the means and medians were close, the standard deviations were either close to, or larger than the means. The normality tests showed significant p-values below 0.05, (Kolmogorov-Smirnov and Shapiro-Wilk), the histograms showed no distinctive bell-curve and the normality plots showed many points falling off the line.

For total sitting times, the means and medians were close, the standard deviations were less than half of the means, the normality tests showed no significant p-values below 0.05, although the normality plots showed points falling off the line and no distinct bell curve on the histograms.

Marshall Sitting Questionnaire inclusion & exclusion criteria

Following the preliminary analysis to check normality of the MSQ, some of the self-reported MSQ items showed estimates of domain and total sitting time that required some consideration before including or excluding certain participants from all or part of the analyses that included the use of the MSQ.

Although there were no missing values for weekday MSQ, 2 participants provided no weekend MSQ data, and a further 2 participants completed only one item of the weekend MSQ (1=Travel, 1=Leisure). These items were left as missing values as there was no way to tell from visually inspecting the data whether the participant left these blank to be regarded as 0hrs, to be copied from the weekday MSQ items, or whether the participant had simply forgotten to complete them, and so these 4 participants were excluded from weekend day analyses.

One participant responded to the weekend ‘while using a computer’ MSQ item with ‘most of the day’ rather than a numerical value and so this participant was excluded from weekend day analyses.

Three participants had values for both weekday and weekend MSQ items totalling well over 24hrs per day. It was considered that these participants had misread the MSQ instructions and had completed totals for the week for all weekday and weekend days, rather than ‘per day’. Dividing each item by 5 for the weekday MSQ brought these three participant scores in line with distribution of total scores from the other participants. However, for the weekend MSQ items which were divided by 2, the estimated sitting time totals were still considerably higher than the other participants’ responses (22, 24 and 25.5hrs) and so these three participants were

excluded from all analyses using the MSQ to be sure that the included data was a reliable estimation of sitting time.

When checking for a normal distribution of MSQ scores across participants for weekday and weekend day sitting, two participants were identified as having an unusually high estimate of weekend day sitting time at 20hrs, which was 6hrs more than the next highest reported sitting time of 14hrs. One participant also had a weekday total sitting time of 20hrs, which was 3.5hrs more than the next highest reported sitting time of 16.5hrs. There was no standard cut-off point for maximum sitting time in the MSQ within the literature (Chau et al., 2011, 2012; Sasaki et al., 2019), however after conversing with authors of published papers using the MSQ via email, 17hrs was the recommended cut point for identifying unusually high estimates of sitting time. These three participant responses were compared with their ActivPAL3 average weekend/weekday sitting time to determine whether to include or exclude them based on the 17hr recommended cut point, as it had also been suggested by Chau (2011; 2012) via email that given that people with BD have been identified as more sedentary than the general population and were still a relatively new population to be exploring, it may be better to still include scores over 17hrs. However, all three participants had over-estimated their respective sitting time by approximately 10hrs compared to their ActivPAL3 SB data, and so these three participants were excluded from either the weekday or weekend analyses respectively.

The above exclusions meant that 10 participants were excluded from either part or all analysis involving the MSQ (some participants fell into more than one category for exclusion): 6 due to missing data, 4 due to invalid data (over 24hrs), and 3 due to outliers (over 17hrs). In total 41(80%) participants had full MSQ data and were

included for all weekday and weekend analysis involving the use of the MSQ. Forty-four (86%) were included in just weekday analysis, and 42 (82%) were included in just weekend analysis.

Following the above exclusions, all MSQ individual items and totals were re-explored to re-check distribution and parametric assumptions. Following this, there was no change to the distribution of individual domains, and so non-parametric testing was used in analysis to report domain related sitting time. However, the removal of the above outliers and invalid data improved the distribution of the totalled variables, with points sitting on or close to the line on the normality plots. The histograms showed a bell curve with some variation; however this was moderate given the sample size, and therefore parametric tests were considered acceptable in analysis concerning weekday or weekend total sitting time, and when comparing MSQ total sitting time to the ActivPAL3 time spent in SB (hrs).

Body Mass Index

Body Mass Index (BMI) was calculated for the 44 (86%) participants who provided their self-reported weight and height in the study pack. Weight was firstly converted into kilograms (kg), and height into meters (m) using excel functions, before calculating BMI (kg/m^2). BMI was determined and coded as underweight (<18.5), normal (18.5- 24.9), pre-obese (25- 29.9) or obese (30+) by categories defined by the WHO (WHO, 2019; who.int).

Medication

Forty-one participants (80%) self-reported their current medication use in the study pack. Medications were grouped into mood stabilizers, antidepressants, antipsychotics, and anti-anxiety medication based on their primary function in BD using the British National Formulary (BNF, 2019; bnf.nice.org.uk).

Sociodemographic BDRN data

BDRN provided access to sociodemographic data previously collected from their participants. The data used in this study included gender, age (yrs), ethnic origin, self-reported physical health co-morbidities and lifetime psychiatric history: age of BD illness onset (yrs); length of BD illness (yrs); and average number of depressive and (hypo)manic episodes (per illness year). These data was collected by BDRN during initial recruitment, in the processes described in Chapter three.

5.4.1 Data analysis plan

Analysis was planned and structured in line with the study aims and objectives. Figure 5.5 below outlines the analysis plan to meet the objectives of aim 1, followed by Figure 5.6 which outlines the analysis plan to meet the objectives of aim 2. Analysis was carried out in IBM-SPSS-24 (ibm.com).

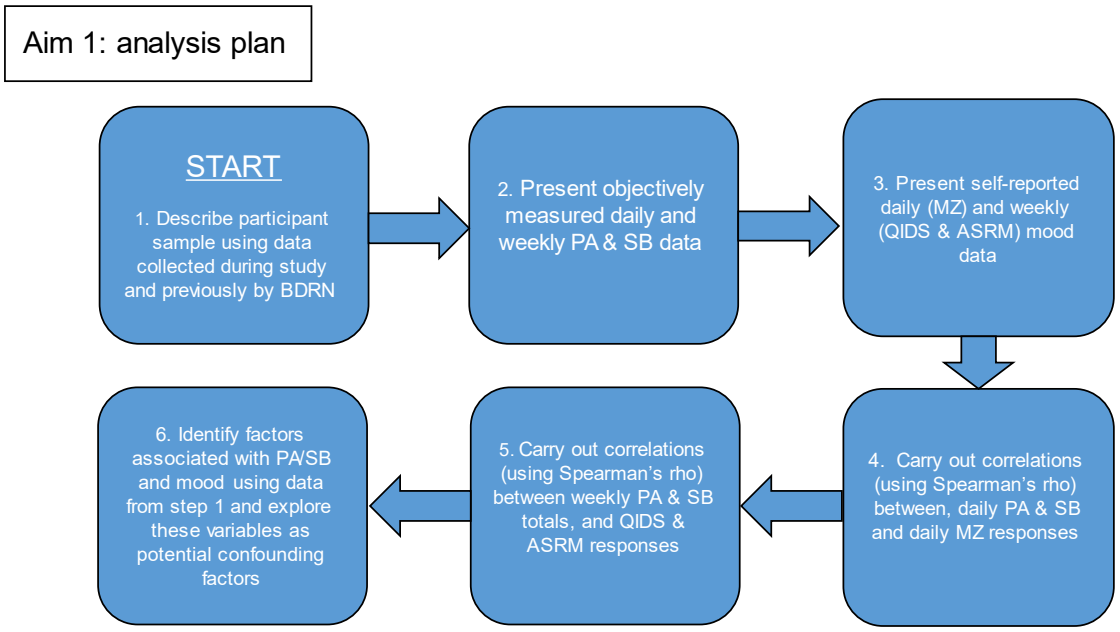


Figure 5.5 Study two analysis plan: aim 1

The majority of the analyses assessed the relationship between PA, SB and non-parametric, continuous, mood variables (ratings data) and so non-parametric Spearman's rho correlation tests were conducted to examine relationships between PA, SB and mood (steps 4 and 5). Parametric tests were used when exploring potential factors associated with PA and SB (where the data were normally distributed) and also for presenting statistical summaries of the PA and SB variables which were normally distributed (steps 2 and 6). Non-parametric testing was used with any analysis concerning variables that were not normally distributed, such as

‘number of bouts lasting over 120mins’, and ‘time spent in bouts lasting over 120mins (hrs),’ and any mood variables.

At step 4, relationships between daily PA, SB and mood over the 7-day period were examined by using Spearman’s rho correlation tests on the individual daily PA and SB ActivPAL3 variables with the individual daily Mood Zoom items. These correlations included up to 7-days of data per participant (depending on their number of valid days/ any missing MZ data). A maximum of 357 days (7-days x 51 participants) was therefore possible in each correlation data.

At step 5, relationships between weekly PA, SB and mood over the 7-day period were examined by using Spearman’s rho correlation tests on the weekly PA and SB ActivPAL3 variables with the QIDS (depression) items and total score, and the ASRM ((hypo)mania) items and total score.

At step 6, variables from step 1 were explored to identify potential confounders in the relationships identified between PA, SB and mood (steps 4 & 5) i.e. factors which were associated with both PA/SB and mood. Nominal variables: *gender (males/females), diagnosis (BDI/BDII), medication (yes/no for each medication) and physical health co-morbidities (yes/no for each condition)* were explored using independent samples t-tests (for variables which met parametric assumptions) and Mann-Whitney U-tests (for variables which did not meet parametric assumptions) to identify statistically significant differences between groups in PA or SB engagement, and mood. Continuous variables: *(age, BMI, number of (hypo)manic episodes per illness year, number of depressive episodes per illness year, length of BD illness(yrs), and age of BD illness onset(yrs))* were explored using Spearman’s rho correlation tests. Where factors were found to be associated with both PA/SB and

mood, any significant analyses from steps 4 and 5 were explored further in relation to these factors (i.e. split by groups).

For all of the above analyses, the significance level was set at $p<0.05$. The effect sizes of correlations are reported in line with Cohen (1988): small (r=0.10-0.29) medium (r=0.30-0.49) and large (r=0.50-1.0).

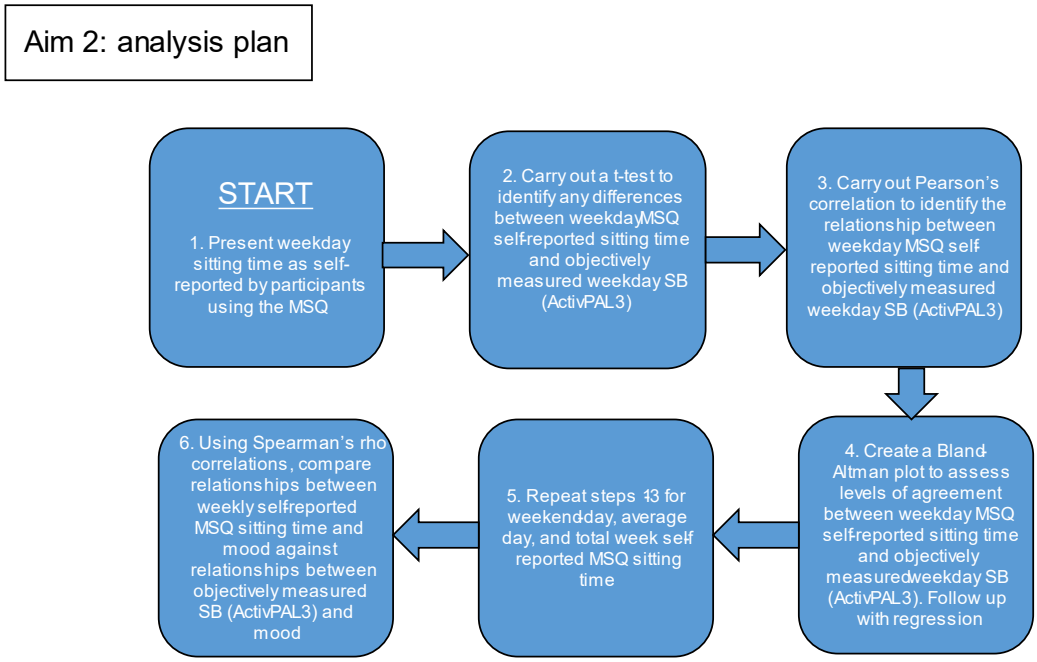


Figure 5.6 Study two analysis plan: aim 2

At step 2, independent samples t-tests were used to explore differences between the means of the two measures (time spent in SB according to the MSQ and time spent in SB according to the ActivPAL3) for the average weekday, weekend day, average day, and total week time spent in SB. At step 3, Pearson's correlation test was used to assess the relationship between the MSQ and ActivPAL3, as these variables were normally distributed and meeting parametric assumptions. Bland-Altman plots (Bland & Altman, 1986) followed at step 4 to determine the agreement and any consistent

bias between the two measures (MSQ sitting time (hrs) and ActivPAL3 SB time (hrs)). A linear regression using the *difference* between the two measures, and the *mean* of the two measures, was then required to identify any proportional bias of either measure over or under estimating SB compared with the other.

At step 6, Spearman's rho correlation tests were used to explore the relationship between total week self-reported MSQ sitting time (hrs) and depression (QIDS total score) and (hypo)mania (ASRM total score) mood symptoms. These correlations were presented alongside the device-measured SB (ActivPAL3) data (from aim 1) to compare the relationships between device-measured SB (activPAL3), and self-reported sitting time (MSQ) with self-reported total mood symptom severity (ASRM and QIDS).

The significance level was set at $p<0.05$ and the effect sizes of correlations are reported in line with Cohen (1988): small (r=0.10-0.29) medium (r=0.30-0.49) and large (r=0.50-1.0).

5.5 Results

5.5.1 Participant descriptive information

Gender

Of the 51 participants who completed the study, 35 (64%) were female, and 16 (31%) were male.

Ethnic origin

Forty-nine participants (96%) reported their ethnic origin as ‘UK white’; one (2%) as ‘West European’, and one (2%) as ‘mixed/multiple ethnic group.’

Age

The youngest participant in the study was 30 years old, and the oldest was 72 (range=42). The mean age was 53.05 (±11.24).

Body Mass Index

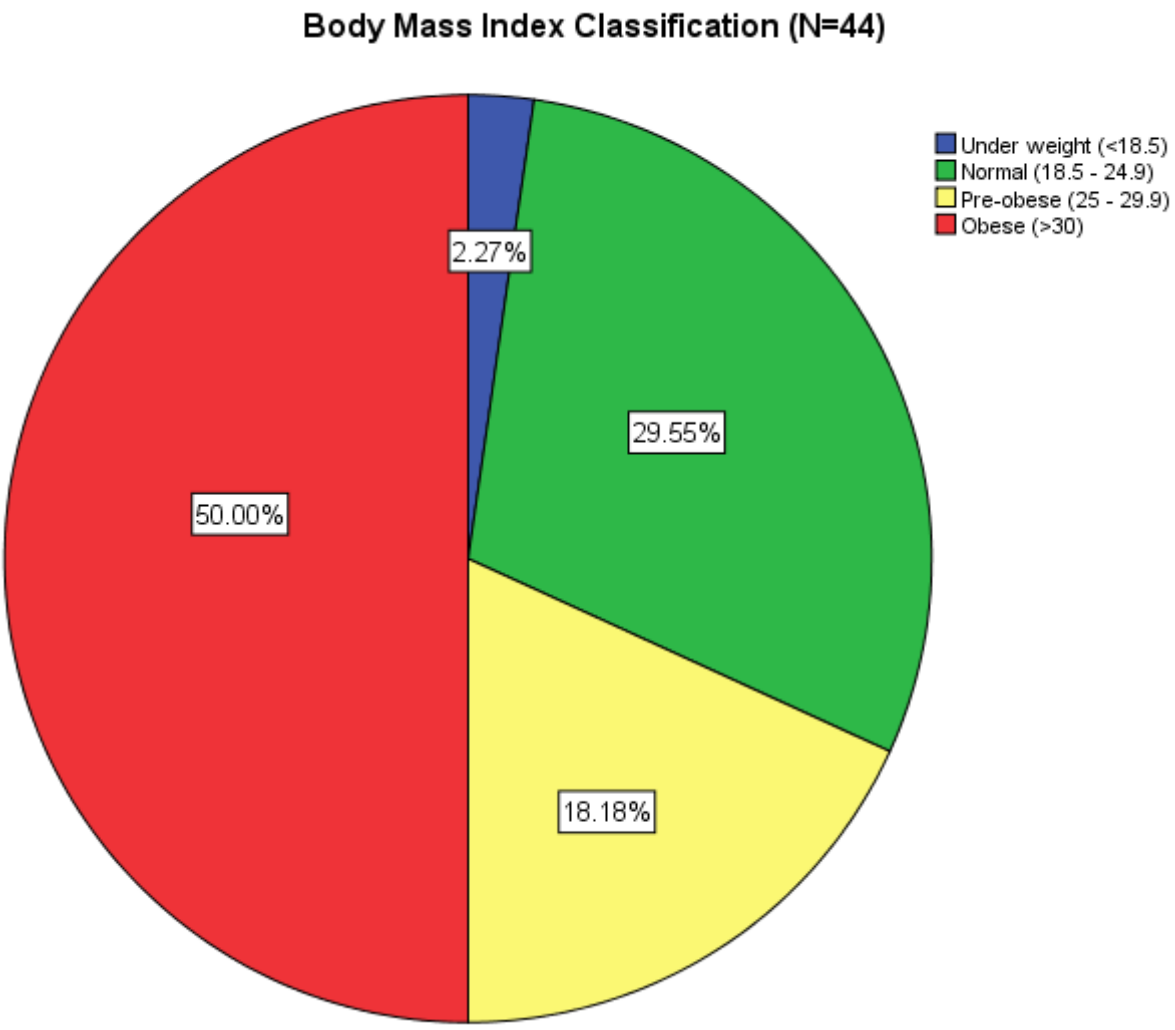


Figure 5.7 BMI classification (WHO, 2019; who.int) of participants who provided self-reported weight & height (N=44, 86%)

Figure 5.7 shows that 68% of the participants for whom BMI was calculated were categorised as ‘pre-obese’ or ‘obese’, 2% were considered ‘underweight’, and 30% were considered to be of a ‘normal’ weight.

Lifetime psychiatric history

Twenty-seven participants (53%) had a best estimate main lifetime DSM-IV diagnosis of BD type I (BDI), and 24 (47%) had a diagnosis of BD type II (BDII) (see Chapter three, page 91 for diagnostic procedure). Table 5.1 below provides summary figures of participants' BD lifetime psychiatric history.

Table 5.1 Lifetime psychiatric history of participants

Lifetime psychiatric history	**Min**	**Max**	**Range**	**Mean (±SD)**
Age of BD illness onset* *(yrs)*	7.00	42.00	35.00	22.14 (9.01)
Length of BD illness *(yrs)*	7.00	51.00	44.00	30.69 (12.01)
Average number of (hypo)manic episodes *(per illness year)*	0.05	0.29	2.24	0.56 (0.60)
Average number of depressive episodes (*per illness year)*	0.00	3.85	3.85	0.70 (0.82)

**onset of symptoms occurring within the context of a mood episode that produce clinically significant impairment (BDRN)*

Medication

Self-reported BD medication used during the study period is summarised in Table 5.2.

Table 5.2 Self-reported BD medication used during study two (N=41, 80%)

Medication type	Self-reported examples	No. and % of participants self-reporting use
Mood stabilizers *(inc. anticonvulsants)*	Lithium *(inc. Priadel)*, Sodium Valproate *(inc. Depakote)*, Lamotrigine, Carbamazepine, Gabapentin	22 (54%)
Anti-depressants	Vortioxetine, Citalopram, Sertraline, Duloxetine, Venlafaxine, Mirtazapine, Fluoxetine, Dosulepin, Amitriptyline	18 (44%)
Anti-psychotics	Quetiapine, Olanzapine, Risperidone, Aripiprazole *(inc. Abilify liquid)*	21 (51%)
Anti-anxiety	Diazepam, Pregabalin, Lorazepam, Propranolol	8 (20%)

Table 5.2 summarises the medication by way of its primary function when used to treat or manage symptoms of BD (hypo)mania or depression, as well as any psychosis (BNF, 2019; bnf.nice.org.uk), although it is acknowledged that these medications may have been prescribed for multiple or other purposes. Table 5.2 shows that the most common BD medications used during the study period were mood stabilizers, followed by anti-psychotics, anti-depressants, and then anti-anxiety medication. The most frequently reported medication was the anti-psychotic Quetiapine (N=10, 24% of those who self-reported medication) followed by mood-stabilizer Lithium (N=7, 17%).

Eighty-six different individual medications were reported as being ‘current medication use’. These included medications other than those used in managing BD symptoms,

although these medications were wide-spread and the number of participants reporting each of these other medications were small. The most common non-BD related medication reported was Levothyroxine (N=8, 20%) which is used to treat an underactive thyroid (hypothyroidism; BNF, 2019; bnf.nice.org.uk)

Physical health co-morbidities

Participants had previously provided BDRN with information on some physical health comorbidities after completing a medical history questionnaire, developed by BDRN researchers (see Chapter three, page 91). The questionnaire asked if they had ever been told by a health professional that they have the listed conditions. The most frequently reported conditions for participants in this study included: type II diabetes (N=4, 8%); cancer (N=6, 12%); osteoarthritis (N=6, 12%); hypertension (N=8, 16%); asthma (N=10, 20%); migraines (N=13, 26%); elevated cholesterol (N=16, 31%); and thyroid disease (unspecified N=2, 4%; hyperthyroid N=2, 4%; hypothyroid N=10, 20%).

5.5.2 Device-measured physical activity & sedentary behaviour

Aim 1: objective 1: To quantify and report daily, and weekly PA and SB in people living with BD using the ActivPAL3 activity monitor.

Table 5.3 below shows the descriptive statistics of daily and weekly PA, and Table 5.4 shows daily and weekly SB, as measured by the ActivPAL3. As only 44 participants had 7-valid days of data, only these participants are represented in the 'totals' section of the tables below to avoid the data being misrepresented by those whose totals only represent 3-6 days of data.

Table 5.3 Descriptive statistics of daily and weekly PA as measured by the ActivPAL3

	Daily: average day (N=51)				**Weekly: total for the 7-day period (N=44)**			
ActivPAL3 PA Variables	**Min**	**Max**	**Range**	**Mean (±SD)**	**Min**	**Max**	**Range**	**Mean (±SD)**
Time spent standing (hrs)	0.95	6.95	6.00	4.11 (1.49)	6.34	48.64	42.30	30.03 (9.78)
Time spent stepping (walking) (hrs)	0.32	3.30	2.98	1.64 (0.66)	3.44	22.84	19.40	12.18 (4.43)
Number of steps	689.00	9634.25	8945.25	3819.09 (1732.5)	8119.00	66032.00	57913.00	28275.57 (11929.38)
Time spent in light intensity PA (hrs)	0.15	1.31	1.16	0.67 (0.28)	1.57	9.15	7.58	5.01 (1.84)
Time spent in MVPA (hrs)	0.17	2.56	2.40	0.97 (0.46)	1.87	17.32	15.45	7.17 (3.23)

	Daily: average day (N=51)				Weekly: total for the 7-day period (N=44)			
ActivPAL3 PA Variables	**Min**	**Max**	**Range**	**Mean (±SD)**	**Min**	**Max**	**Range**	**Mean (±SD)**
Number of SB to upright transitions	24.20	85.29	61.09	53.60 (16.33)	196.00	597.00	401.00	384.73 (110.32)

Table 5.3 shows that on average participants spent more time standing (4hrs 6mins) than stepping/walking (1hrs 38mins), and of the time spent stepping/walking, more time was spent in MVPA per day (58mins) than in light intensity PA (40mins). The average number of steps per day showed a large range (8945.25) which was greater than the mean (3819.09), indicating substantial variability between participants daily step count.

Table 5.4 Descriptive statistics of daily and weekly SB as measured by the ActivPAL3

	Daily: average day (N=51)				Weekly: total for the 7-day period (N=44)			
ActivPAL3 SB Variables	**Min**	**Max**	**Range**	**Mean (±SD) OR **Median (IQR)***	**Min**	**Max**	**Range**	**Mean (±SD) OR **Median (IQR)***
Time spent in SB (hrs)	6.67	14.00	7.32	9.93 (1.74)	46.71	97.55	50.84	69.28 (12.81)
Number of SB bouts	24.60	85.57	60.97	53.81 (16.32)	197.00	599.00	402.00	386.25 (110.33)
Number of SB bouts lasting 0-30mins	18.00	83.14	65.14	48.33 (17.52)	144.00	582.00	438.00	348.86 (118.59)
Time spent in SB bouts lasting 0-30mins (hrs)	2.03	8.52	6.49	4.46 (1.26)	14.24	59.66	45.42	31.75 (9.3)

	Daily: average day (N=51)				Weekly: total for the 7-day period (N=44)			
ActivPAL3 SB Variables	**Min**	**Max**	**Range**	**Mean (±SD) OR *Median (IQR)***	**Min**	**Max**	**Range**	**Mean (±SD) OR *Median (IQR)***
Number of SB bouts lasting 30-60mins	1.57	6.60	5.03	3.53 (1.16)	11.00	46.00	35.00	23.75 (7.61)
Time spent in SB bouts lasting 30-60mins (hrs)	1.09	4.53	3.44	2.48 (0.82)	7.61	31.68	24.07	16.83 (5.59)
Number of SB bouts lasting 60-120mins	0.00	4.29	4.29	1.68 (0.96)	0.00	30.00	30.00	11.75 (6.85)
Time spent in SB bouts lasting 60-120mins (hrs)	0.00	5.96	5.96	2.28 (1.33)	0.00	41.75	41.75	15.75 (9.42)
Number of SB bouts lasting over 120mins	0.00	1.00	1.00	**0.29 (0.00, 0.43)*	0.00	7.00	7.00	**2.00 (1.00, 3.00)*
Time spent in SB bouts lasting over 120mins (hrs)	0.00	3.06	3.06	**0.62 (0.00, 1.01)*	0.00	21.40	21.40	**4.50 (2.14, 7.04)*

**The variables relating to number of bouts lasting over 120mins were not normally distributed. The ActivPAL3 data frequently reported '0' for this category, which made the daily average less than 120mins. E.g. participant-1 had 6 days spending 0mins in sitting bouts lasting over 120mins, but one day spending 3.5hrs in a single bout, which averaged at 0.5hrs for the 7-days. The mean of these two variables was therefore replaced with the median value, and SD with IQR.*

Table 5.4 shows that, overall, more time was spent in bouts lasting 0-30mins than bouts lasting 30-60mins, 60-120mins or bouts lasting over 120mins. More time was also spent in bouts lasting 30-60mins than bouts lasting over 120mins, and more time was spent in bouts lasting 60-120mins, than bouts lasting over 120mins.

Table 5.3 and 5.4 collectively show that participants spent on average most of their time each day being sedentary (9hrs 56mins), and 5hrs 44mins being physically

active, the majority of which was stationary behaviour (standing:4hrs 6mins v stepping/walking:1hr 38mins). Table 5.3 shows that all participants spent 7hrs and 8mins a week in MVPA, and therefore met the recommended CMO guidelines. Table 5.3 and 5.4 also show that the average number of SB to upright transitions per day (24.20) is relative to the number of SB bouts (24.60). This is expected given that an upright to SB movement would start an SB bout, and an SB to upright transition would end an SB bout.

5.5.3 Self-reported daily & weekly mood symptoms

Aim 1, objective 2: To gather self-reported daily (Mood Zoom) and weekly depressive (QIDS) and (hypo)manic (ASRM) mood symptoms in people living with BD.

Daily mood

Averaged (median) daily Mood Zoom scores for all participants over the 7-day period (per mood symptom) are presented in Figure 5.8 below (N=51).

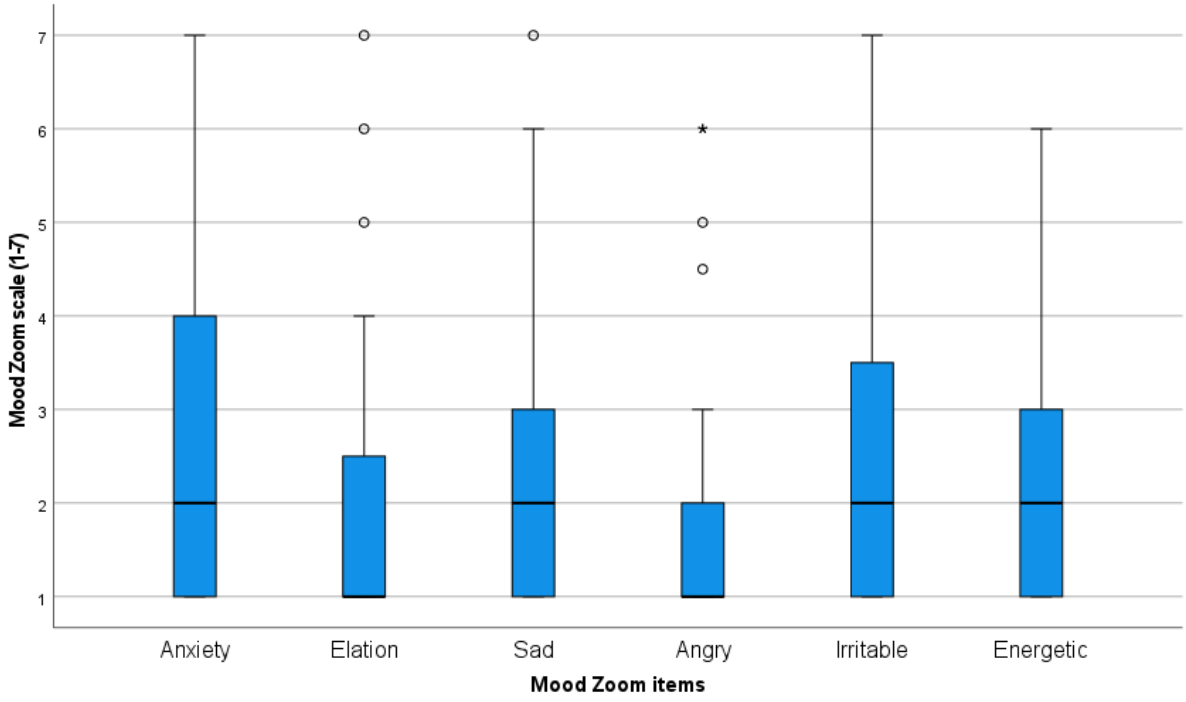


Figure 5.8 Distribution of averaged daily Mood Zoom scores (1-7) (N=51)

Figure 5.8 shows that overall anxiety was the most severe daily mood symptom for the 7-day period (*Md*=2, *IQR*: 1, 4), followed by feeling irritable (*Md*=2, *IQR*: 1, 4); energetic (*Md*=2, *IQR*: 1, 3); sad (*Md*=2, *IQR*: 1, 3); and elated (*Md*=1, *IQR*: 1, 3); with anger (*Md*=1, *IQR*: 1, 2) the least severe symptom of daily mood overall. A total of 8 participants (outliers) experienced more severe symptoms of mood compared to

other participants, showing higher self-reports of both ‘elation’ and ‘anger’ than most other participants. The median was ‘2’ or ‘1’ for all items, indicating low variability over the 7-days between and within participant MZ scores, and so most participants were not experiencing severe mood symptoms during the 7-days they wore the ActivPAL3.

Weekly mood: Depression

The spread of individual QIDS item scores (0-3) are shown in Table 5.5 below.

Table 5.5 Distribution of individual depression symptoms (QIDS)

	Frequency and percentages of individual responses			
QIDS item	**0**	**1**	**2**	**3**
QIDS1: Falling asleep (N=51)	24 (47%)	8 (16%)	11 (22%)	8 (16%)
QIDS2: Sleep during the night (N=51)	10 (20%)	12 (24%)	16 (31%)	13 (26%)
QIDS3: Waking up too early (N=51)	25 (49%)	18 (35%)	5 (10%)	3 (6%)
QIDS4: Sleeping too much (N=51)	23 (45%)	17 (33%)	6 (12%)	5 (10%)
QIDS5: Feeling sad (N=51)	21 (41%)	15 (29%)	11 (22%)	4 (8%)
QIDS6: Decreased appetite (N=49)	35 (69%)	10 (20%)	4 (8%)	0 (0%)
QIDS7: Increased appetite (N=49)	39 (77%)	3 (6%)	4 (8%)	3 (6%)
QIDS8: Decreased weight (N=48)	35 (69%)	9 (18%)	4 (8%)	0 (0%)
QIDS9: Increased weight (N=48)	38 (75%)	6 (12%)	1 (2%)	3 (6%)
QIDS10: Concentration/ decision making (N=50)	17 (33%)	16 (31%)	15 (29%)	2 (4%)
QIDS11: View of self (N=50)	23 (45%)	10 (20%)	10 (20%)	7 (14%)
QIDS12: Thoughts of death or suicide (N=50)	28 (55%)	11 (22%)	10 (20%)	1 (2%)
QIDS13: General interest (N=50)	24 (47%)	9 (18%)	13 (26%)	4 (8%)
QIDS14: Energy level (N=50)	20 (39%)	16 (31%)	9 (18%)	5 (10%)
QIDS15: Feeling slowed down (N=50)	34 (67%)	8 (16%)	6 (12%)	2 (4%)
QIDS16: Feeling restless (N=50)	27 (53%)	12 (24%)	7 (14%)	4 (8%)

Table 5.5 shows that individual QIDS items measuring severity of depressive symptoms were mostly clustered towards the less severe (left end) of the scale, and that the average score for each item was ‘0’ with the exception of QIDS item 2 ‘sleep during the night’ which shows an average score of ‘2’ as well as the most variation in

scores. Items 7 ‘increased appetite’ and 9 ‘increased weight’ showed the least variation in scores. Table 5.5 indicates that whilst some participants were experiencing symptoms of depression during the study period, the majority of participants were not experiencing severe symptoms of depression.

Total scores for depression (using the QIDS) for the 7-day period are shown in Figure 5.9 below (N=51):

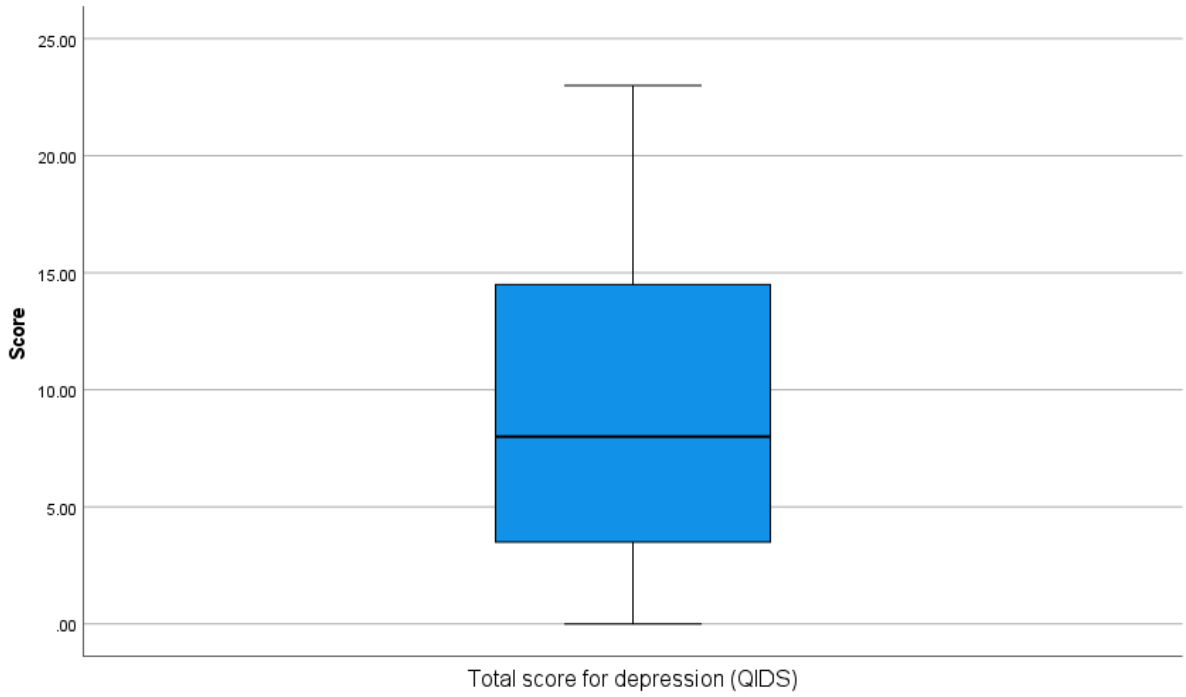


Figure 5.9 Distribution of depression (QIDS) total score (N=51)

Figure 5.9 shows scores ranged from 0 to 23 out of the possible 27 (*Md*=8 *IQR*: 3, 15).

Weekly mood: (Hypo)mania

The distribution of individual ASRM item scores (0-4) are shown in Table 5.6 below.

Table 5.6 Frequency of individual (hypo)mania (ASRM) symptoms (N=51)

	Frequency and percentages of individual responses				
ASRM item	0	1	2	3	4
ASRM1: Happiness	28 (55%)	13 (26%)	6 (12%)	3 (6%)	1 (2%)
ASRM2:Confidence	33 (65%)	9 (18%)	6 (12%)	3 (6%)	0 (0%)
ASRM3: Sleep	42 (82%)	3 (6%)	3 (6%)	2 (4%)	1 (2%)
ASRM4:Talking	30 (59%)	9 (18%)	7 (14%)	5 (10%)	0 (0%)
ASRM5:Activity	30 (59%)	12 (24%)	6 (12%)	2 (4%)	1 (2%)

Table 5.6 shows that all individual ASRM items measuring severity of (hypo)manic symptoms were clustered towards the less severe (left end) of the scale, and that the majority of individual item scores were ‘0’ for all items. All ASRM items showed little variation, with item 3 (less need for sleep) showing the least amount of variation in scores. Table 5.6 indicates that the majority of participants were not experiencing severe symptoms of (hypo)mania during the study period.

Total scores for (hypo)mania (using the ASRM) for the 7-day period are shown in Figure 5.10 below (N=51).

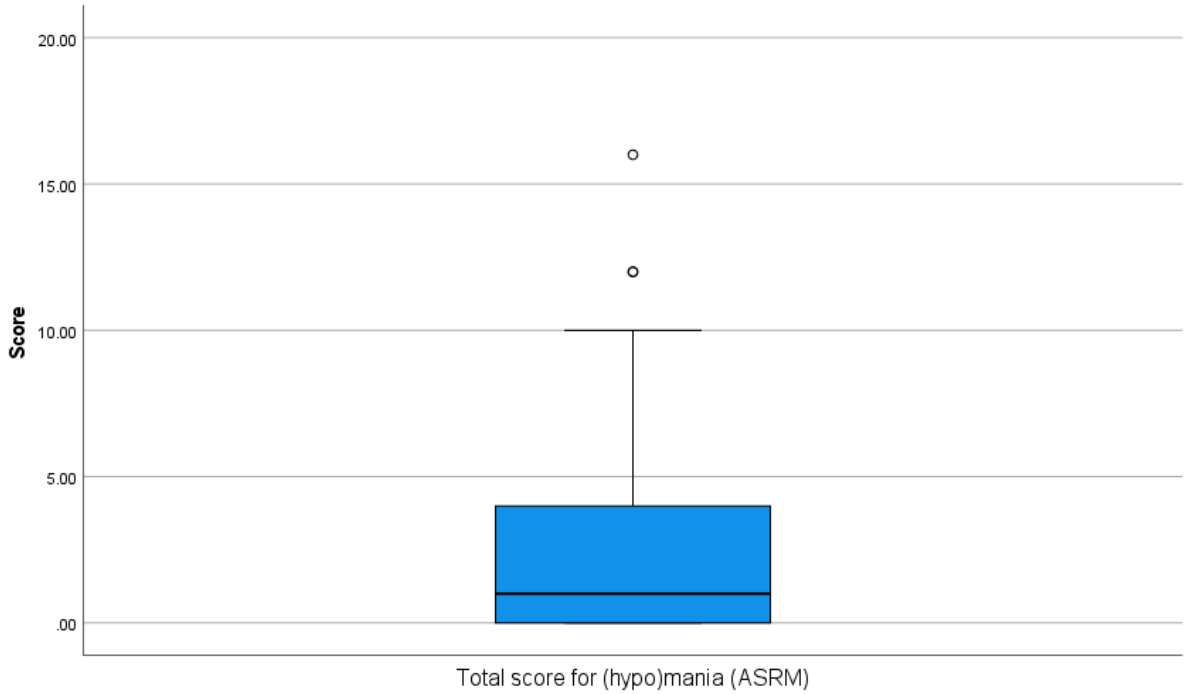


Figure 5.10 Distribution of (hypo)mania (ASRM) total scores (N=51)

Figure 5.10 shows scores ranged from 0 to 16 out of the possible 20 (*Md*=1, *IQR*: 1, 4). Three participants scored considerably higher (above 10) for (hypo)mania than other participants, indicating they experienced more severe levels of (hypo)mania than other participants. Most participants scored between 0 and 4, indicating no (hypo)mania during the study period.

Weekly mood: mood state

Participant mood state for the 7-day period is presented in Figure 5.11 below, as measured and determined by the diagnostic cut-off values of the QIDS (Rush et al., 2003) and ASRM (Altman et al., 1997) criteria for (hypo)mania and depression severity to describe the mood state of the participant sample at time of participation.

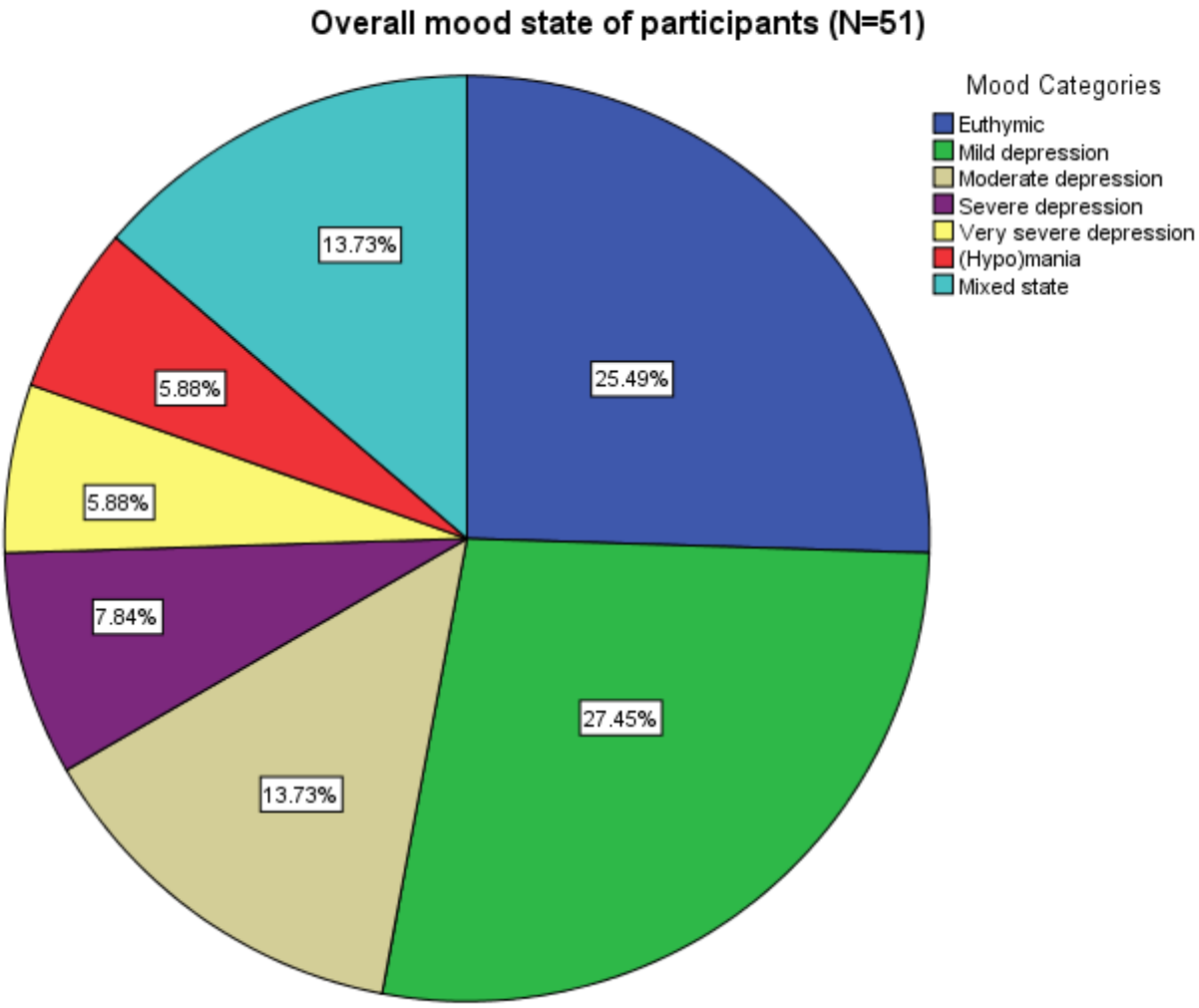


Figure 5.11 Mood state for the 7-day period using QIDS & ASRM total scores to categorise mood (N=51)

Figure 5.11 shows that 55% of participants were experiencing depression, with mild depression being the most common mood state (27%). More participants were

considered to be experiencing mixed mood symptoms (14%) rather than (hypo)mania (6%), and 25% of participants were experiencing no significant mood symptoms as measured by the QIDS and ASRM at the time of participating and were therefore considered euthymic.

5.5.4 Relationships between device-measured daily physical activity, sedentary behaviour & self-reported mood symptoms

Aim 1, objective 3: To explore the relationships between device-measured daily PA, SB, and self-reported BD mood symptoms (Mood Zoom) over a 7-day period.

Table 5.7 below shows the relationship between individual daily PA and SB obtained from the ActivPAL3.

Table 5.7 Correlations between daily PA & SB (N=345)

		Daily PA ActivPAL3 Variables						
		Time spent standing (hrs)	**Time spent stepping (walking) (hrs)**	**Number of steps**	**Time spent in light intensity PA (hrs)**	**Time spent in MVPA (hrs)**	**Number of SB to upright transitions**	**Number of significant correlations**
Daily SB ActivPAL3 Variables	**Time spent in SB (hrs)**	*-0.539****	*-0.466****	*-0.459****	*-0.425****	*-0.429****	-0.073	5
	Number of SB bouts	*0.361****	*0.353****	*0.301****	*0.462****	*0.253****	*1.000****	6
	Number of SB bouts lasting 0-30mins	*0.416****	*0.398****	*0.346****	*0.500****	*0.298****	*0.992****	6
	Time spent in SB bouts lasting 0-30mins (hrs)	*0.086*	*0.144***	*0.125**	*0.203****	*0.114**	*0.716****	5
	Number of SB bouts lasting 30-60mins	*-0.359****	*-0.367****	*-0.350****	*-0.348****	*-0.331****	*-0.239****	6
	Time spent in SB bouts lasting 30-60mins (hrs)	*-0.372****	*-0.383****	*-0.364****	*-0.363****	*-0.345****	*-0.262****	6
	Number of SB bouts lasting 60-120mins	*-0.376****	*-0.273****	*-0.266****	*-0.285****	*-0.246****	*-0.297****	6

		Daily PA ActivPAL3 Variables						
		Time spent standing (hrs)	**Time spent stepping (walking) (hrs)**	**Number of steps**	**Time spent in light intensity PA (hrs)**	**Time spent in MVPA (hrs)**	**Number of SB to upright transitions**	**Number of significant correlations**
Daily SB ActivPAL3 Variables	**Time spent in SB bouts lasting 60-120mins (hrs)**	*-0.373***	*-0.281***	*-0.274***	*-0.294***	*-0.251***	*-0.305***	6
	Number of SB bouts lasting over 120mins	*-0.211***	*-0.189***	*-0.186***	*-0.189***	*-0.169***	*-0.276***	6
	Time spent in SB bouts lasting over 120mins (hrs)	*-0.199***	*-0.182***	*-0.182***	*-0.177***	*-0.168***	*-0.265***	6

**p<0.05, **p<0.01, ***p<0.001*

Table 5.7 above shows negative associations between all PA variables with SB variables except ‘number of SB bouts,’ ‘number of SB bouts lasting 0-30mins’ and ‘time spent in SB bouts lasting 0-30mins’ which show positive associations. The strongest correlation observed is a strong positive association between ‘number of SB bouts’ and ‘number of SB to upright transitions’ followed by medium strength negative associations of ‘time spent in SB’ with PA variables ‘time spent standing,’ ‘time spent stepping’ ‘number of steps taken,’ ‘time spent in light PA’ and ‘time spent in MVPA.’

Table 5.8 below shows the relationship between individual daily PA obtained from the ActivPAL3 and self-reported mood symptoms (MZ).

Table 5.8 Correlations between daily PA and daily mood symptoms

	Mood Zoom Items						
ActivPAL3 PA variables	**Anxiety N=341**	**Elation N=342**	**Sadness N=341**	**Angry N=341**	**Irritable N=341**	**Energetic N=342**	**Number of significant correlations**
Time spent standing (hrs)	0.029	*0.121**	*-0.128***	0.028	0.023	*0.261****	3
Time spent stepping (walking) (hrs)	-0.076	*0.169***	*-0.222****	-0.035	*-0.153***	*0.320****	4
Number of steps	-0.093	*0.187****	*-0.240****	-0.038	*-0.153***	*0.344****	4
Time spent in light intensity PA (hrs)	-0.017	0.079	*-0.108**	-0.005	*-0.122**	*0.187****	3
Time spent in MVPA (hrs)	-0.095	*0.189****	*-0.243****	-0.046	*-0.149***	*0.340****	4
Number of SB to upright transitions	0.078	0.051	-0.034	0.051	0.089	0.033	0

**p<0.05 **p<0.01, ***p<0.001*

Table 5.8 shows significant negative associations between PA *('time spent standing', 'time spent stepping,' 'number of steps taken,' 'time spent in light PA' and 'time spent in MVPA')* and feeling 'sad', and positive associations with feeling 'energetic'. PA *('time spent standing,' 'time spent stepping,' 'time spent in MVPA', and 'number of steps' taken)* showed positive associations with feeling 'elated.' PA also showed negative associations *('time spent stepping' and 'number of steps taken')* with feeling 'irritable.' The strongest correlation observed is a positive association of medium

strength between the ‘number of steps taken,’ and feeling ‘energetic’ followed by ‘time spent in MVPA’ and ‘feeling energetic,’ also of medium strength.

Table 5.9 below shows the relationship between individual daily SB obtained from the ActivPAL3 and self-reported mood symptoms (MZ).

Table 5.9 Correlations between daily SB and daily mood symptoms

	Mood Zoom items						
ActivPAL3 SB variables	**Anxiety N=341**	**Elation N=342**	**Sadness N=341**	**Angry N=341**	**Irritable N=341**	**Energetic N=342**	**Number of significant correlations**
Time spent in SB (hrs)	-0.007	-0.055	0.073	0.038	0.065	*-0.208****	1
Number of SB bouts	0.078	0.053	-0.037	0.052	0.087	0.033	0
Number of SB bouts lasting 0-30mins	0.077	0.056	-0.046	0.041	0.077	0.054	0
Time spent in SB bouts lasting 0-30mins (hrs)	0.015	0.026	-0.099	0.026	0.049	0.029	0
Number of SB bouts lasting 30-60mins	-0.038	-0.054	0.067	0.072	0.038	-0.074	0
Time spent in SB bouts lasting 30-60mins (hrs)	-0.035	-0.060	0.080	0.055	0.032	-0.101	0
Number of SB bouts lasting 60-120mins	-0.054	-0.061	0.052	-0.045	-0.030	-0.093	0
Time spent in SB bouts lasting 60-120mins (hrs)	-0.049	-0.058	0.060	-0.032	-0.020	-0.101	0
Number of SB bouts lasting over 120mins	0.038	-0.072	*0.113**	0.026	0.018	*-0.252****	2
Time spent in SB bouts lasting over 120mins (hrs)	0.045	-0.078	*0.121**	0.036	0.032	*-0.256****	2

**p<0.05, **p<0.01, ***p<0.001*

Table 5.9 shows a positive association between ‘number of bouts lasting over 120mins’ and ‘time spent in bouts lasting over 120mins’ with feeling ‘sad’. SB variables ‘time spent in SB’, ‘number of bouts lasting over 120mins’ and ‘time spent in bouts lasting over 120min’ showed significant negative associations with feeling ‘energetic’. No other SB variables showed significant associations with daily mood.

Table 5.8 and 5.9 show that daily ‘anxiety’ and ‘anger’ showed no significant correlations with daily PA or SB.

5.5.5 Relationships between device-measured weekly physical activity, sedentary behaviour & self-reported mood symptoms

Aim 1, objective 4: To explore the relationships between device-measured weekly PA, SB and self-reported depressive (QIDS) and (hypo)manic (ASRM) BD mood symptoms.

Table 5.10 below shows the relationship between weekly PA and SB obtained from the ActivPAL3.

Table 5.10 Correlations between weekly totalled PA & SB (N=44)

		Weekly Totalled PA ActivPAL3 Variables						
		Time spent standing (hrs)	**Time spent stepping (walking) (hrs)**	**Number of steps**	**Time spent in light intensity PA (hrs)**	**Time spent in MVPA (hrs)**	**Number of SB to upright transitions**	**Number of significant correlations**
Weekly Totalled SB ActivPAL3 Variables	**Time spent in SB (hrs)**	*-0.531***	*-0.533***	*-0.485***	*-0.468***	*-0.451***	-0.131	5
	Number of SB bouts	0.265	*0.401***	0.324*	*0.538***	0.260	*1.000***	4
	Number of SB bouts lasting 0-30mins	0.315*	*0.443***	0.366*	*0.567***	0.299*	*0.993***	6
	Time spent in SB bouts lasting 0-30mins (hrs)	0.045	0.155	0.146	0.201	0.144	*0.780***	1
	Number of SB bouts lasting 30-60mins	*-0.473***	*-0.574***	*-0.475***	*-0.579***	*-0.432***	*-0.523***	6
	Time spent in SB bouts lasting 30-60mins (hrs)	*-0.466***	*-0.563***	*-0.469***	*-0.556***	*-0.431***	*-0.541***	6
	Number of SB bouts lasting 60-120mins	*-0.443***	*-0.358**	*-0.345**	*-0.343**	*-0.321**	*-0.448***	*6*

		Weekly Totalled PA ActivPAL3 Variables						
		Time spent standing (hrs)	**Time spent stepping (walking) (hrs)**	**Number of steps**	**Time spent in light intensity PA (hrs)**	**Time spent in MVPA (hrs)**	**Number of SB to upright transitions**	**Number of significant correlations**
Weekly totalled SB ActivPAL3 Variables	**Time spent in SB bouts lasting 60-120mins (hrs)**	*-0.411***	*-0.364**	*-0.362**	*-0.321**	*-0.338**	*-0.466***	6
	Number of SB bouts lasting over 120mins	-0.181	*-0.303**	-0.294	-0.212	-0.272	*-0.324**	2
	Time spent in SB bouts lasting over 120mins (hrs)	-0.137	*-0.285***	-0.294	-0.157	-0.286	-0.236	1

**p<0.05, **p<0.01, ***p<0.001*

Table 5.10 above shows negative associations between all PA variables with SB variables except for 'the number of SB bouts,' 'number of SB bouts lasting 0-30mins' and 'time spent in SB bouts lasting 0-30mins,' and 'number of SB bouts lasting over 120mins' and 'time spent in SB bouts lasting over 120mins'. The strongest association observed is a strong positive association between 'number of SB bouts' and 'number of SB to upright transitions' followed by strong, positive associations of 'number of SB bouts lasting 0-30mins' and 'time spent in SB bouts lasting 0-30mins' with 'number of SB to upright transitions.'

Table 5.11 below shows the relationship between weekly PA obtained from the ActivPAL3, and depressive symptoms and total score (QIDS).

Table 5.11 Correlations between weekly totalled PA & depressive symptoms (QIDS)

	Sleep items				**Sadness**	**Weight/appetite items**				**Decision**	**View of self**	**Suicide**	**Interest**	**Energy**	**Psychomotor items**			
ActivPAL3 totalled PA variables	QIDS 1 N=44	QIDS 2 N=44	QIDS 3 N=44	QIDS 4 N=44	QIDS 5 N=44	QIDS 6 N=42	QIDS 7 N=42	QIDS 8 N=42	QIDS 9 N=42	QIDS 10 N=43	QIDS 11 N=43	QIDS 12 N=43	QIDS 13 N=43	QIDS 14 N=43	QIDS 15 N=43	QIDS 16 N=43	QIDS Total Score N=44	Number of significant correlations
Time spent standing (hrs)	-0.283	*-0.341**	0.102	-0.201	-0.137	0.118	-0.088	0.189	-0.002	-0.189	-0.199	-0.195	-0.135	-0.067	-0.181	0.032	-0.007	1
Time spent stepping (walking) (hrs)	*-0.543***	*-0.305**	-0.158	*-0.340**	*-0.413***	-0.250	-0.052	0.102	-0.052	*-0.362***	-0.268	*-0.412***	*-0.421***	*-0.307**	*-0.499***	-0.203	*-0.324**	10
Number of steps	*-0.528****	-0.207	-0.157	-0.415**	*-0.467***	-0.235	-0.060	0.109	-0.048	*-0.390***	-0.284	*-0.424***	*-0.463***	*-0.374***	*-0.510****	-0.222	*-0.360***	9
Time spent in light intensity PA (hrs)	*-0.431***	*-0.517****	-0.199	-0.186	-0.208	-0.128	-0.002	0.111	-0.026	-0.257	-0.179	-0.238	-0.168	-0.081	*-0.362***	-0.129	-0.152	3
Time spent in MVPA (hrs)	*-0.555****	*-0.163**	-0.148	*-0.417***	*-0.525****	-0.256	-0.084	0.103	-0.089	*-0.400***	-0.286	*-0.475***	*-0.512****	*-0.381***	*-0.508***	-0.242	*-0.421***	10
Number of SB to upright transitions	-0.114	-0.181	-0.085	0.032	-0.080	0.210	-0.152	0.227	-0.205	-0.099	-0.046	-0.073	-0.118	-0.096	*-0.317**	0.060	-0.097	1

**p<0.05, **p<0.01, ***p<0.001*

Table 5.11 shows that three PA variables: ‘time spent in MVPA’, ‘time spent stepping’, and ‘number of steps taken’ showed negative, medium strength associations with the total score for depression. Table 5.11 also identifies several negative associations between PA variables and individual depressive mood symptoms. The strongest of these are negative associations between ‘time spent in light intensity PA,’ ‘time spent in MVPA,’ ‘time spent stepping’ and ‘number of steps taken’ with mood symptoms relating to *‘sleep,’ ‘sadness,’ ‘suicidal thoughts,’* an *‘increased lack of interest,’* and *‘psychomotor’* symptoms. The strongest association observed between PA and depressive mood symptom severity observed is a strong negative association between ‘time spent in MVPA’ and *‘time taken to fall asleep.*’ The PA variables with the most significant number of negative associations with mood symptoms were ‘time spent stepping’, and ‘time spent in MVPA’ (both N=10).

Table 5.12 below shows the relationship between weekly SB obtained from the ActivPAL3 and depressive symptoms (QIDS).

Table 5.12 Correlations between weekly totalled SB & depressive symptoms (QIDS)

	Sleep items				**Sadness**	**Weight/appetite items**				**Decision**	**View of self**	**Suicide**	**Interest**	**Energy**	**Psychomotor items**			
ActivPAL3 totalled SB variables	QIDS 1 N=44	QIDS 2 N=44	QIDS 3 N=44	QIDS 4 N=44	QIDS 5 N=44	QIDS 6 N=42	QIDS 7 N=42	QIDS 8 N=42	QIDS 9 N=42	QIDS 10 N=43	QIDS 11 N=43	QIDS 12 N=43	QIDS 13 N=43	QIDS 14 N=43	QIDS 15 N=43	QIDS 16 N=43	QIDS Total Score N=44	Number of significant correlations
Time spent in SB (hrs)	*0.302**	*0.480***	0.195	0.169	0.148	0.268	-0.041	-0.065	0.071	0.317	0.233	0.270	0.205	0.255	*0.345****	0.141	0.119	3
Number of SB bouts	-0.118	-0.183	-0.084	0.033	-0.081	0.213	-0.157	0.224	-0.205	-0.100	-0.051	-0.076	-0.123	-0.095	*-0.316**	0.056	-0.100	1
Number of SB bouts lasting 0-30mins	-0.148	-0.224	-0.115	0.015	-0.096	0.178	-0.167	0.222	-0.222	-0.116	-0.070	-0.083	-0.129	-0.131	*-0.344**	0.049	-0.096	1
Time spent in SB bouts lasting 0-30mins (hrs)	-0.076	0.013	-0.019	-0.009	-0.211	0.209	-0.279	0.202	*-0.323**	-0.068	-0.075	-0.024	-0.123	-0.097	-0.186	0.047	-0.216	1
Number of SB bouts lasting 30-60mins	0.149	0.294	0.092	0.048	0.133	0.015	-0.343	-0.057	-0.008	0.122	0.026	0.089	0.027	0.101	*0.391***	-0.038	0.025	1
Time spent in SB bouts lasting 30-60mins (hrs)	0.150	0.276	0.059	0.054	0.162	-0.008	-0.028	-0.089	-0.032	0.091	0.007	0.076	0.026	0.083	*0.380***	-0.026	0.011	1
Number of SB bouts lasting 60-120mins	0.155	*0.370**	0.148	0.128	0.123	0.105	0.204	-0.193	*0.351**	0.225	0.150	0.081	0.203	0.262	*0.318**	0.027	0.088	3
Time spent in SB bouts lasting 60-120mins (hrs)	0.165	*0.359**	0.176	0.148	0.118	0.083	0.192	-0.203	*0.336**	0.230	0.133	0.076	0.229	0.289	*0.333**	0.017	0.086	3

**p<0.05, **p<0.01, ***p<0.001*

	Sleep items				Sadness	Weight/appetite items				Decision	View of self	Suicide	Interest	Energy	Psychomotor items			
ActivPAL3 totalled SB variables	QIDS 1 N=44	QIDS 2 N=44	QIDS 3 N=44	QIDS 4 N=44	QIDS 5 N=44	QIDS 6 N=42	QIDS 7 N=42	QIDS 8 N=42	QIDS 9 N=42	QIDS 10 N=43	QIDS 11 N=43	QIDS 12 N=43	QIDS 13 N=43	QIDS 14 N=43	QIDS 15 N=43	QIDS 16 N=43	QIDS Total Score N=44	Number of significant correlations
Number of SB bouts lasting over 120mins	0.244	0.103	0.079	0.154	0.179	0.324	-0.120	0.066	0.085	0.215	*0.344**	0.206	0.268	0.226	0.130	0.027	0.203	1
Time spent in SB bouts lasting over 120mins (hrs)	0.269	0.080	0.085	0.143	0.214	*0.337**	-0.143	0.078	0.044	0.193	*0.340**	0.230	0.275	0.200	0.088	0.094	0.227	2

**p<0.05, **p<0.01, ***p<0.001*

Table 5.12 shows no significant associations between any SB variables and the total QIDS score for depression, but identifies significant associations between SB variables and depressive mood symptoms. Negative medium strength associations are observed between the 'number of SB bouts,' and 'number of SB bouts lasting 0-30mins.' The strongest associations are positive associations of medium strength observed between 'time spent in SB', 'number of bouts lasting 30-60mins,' and 'time spent in bouts lasting 30-60mins' with *'sleep' and 'psychomotor'* symptoms. The strongest of these was a positive, medium strength association between 'time spent in SB' and *'waking through the night'*. The SB variables with the most significant number of associations across mood symptoms were 'time spent in SB', 'number of SB bouts lasting 60-120mins,' and 'time spent in SB bouts lasting 60-120mins' (all N=3).

From Table 5.11 and 5.12, the mood symptom with the most significant number of associations with PA and SB variables was '*feeling slowed down'* (N=12).

Table 5.13 below shows the relationship between weekly totalled PA obtained from the ActivPAL3, and (hypo)mania symptoms (ARSM).

Table 5.13 Correlations between weekly totalled PA & (hypo)mania symptoms (ASRM) (N=44)

	ASRM Items and total score						
ActivPAL3 totalled PA variables: N=44	**Happiness**	**Confidence**	**Sleep**	**Talking**	**Activity**	**Total score**	**Number of significant correlations**
Time spent standing (hrs)	0.117	-0.046	0.102	-0.295	-0.008	-0.070	0
Time spent stepping (walking) (hrs)	-0.085	-0.055	0.111	*-0.339**	-0.012	-0.194	1
Number of steps	-0.044	-0.036	0.105	-0.270	0.029	-0.168	0
Time spent in light intensity PA (hrs)	-0.138	-0.108	-0.001	*-0.412***	-0.080	-0.212	1
Time spent in MVPA (hrs)	-0.058	-0.035	0.074	-0.242	0.010	-0.179	0
Number of SB to upright transitions	0.007	-0.001	-0.012	-0.060	0.042	-0.028	0

**p<0.05, **p<0.01, ***p<0.001*

Table 5.13 above highlights two significant negative associations of medium strength between 'time spent in light intensity PA' and 'time spent in MVPA' with '*talking more than usual'*.

Table 5.14 shows the relationship between weekly totalled SB obtained from the ActivPAL3 and (hypo)mania symptoms (ASRM).

Table 5.14 Correlations between weekly totalled SB & (hypo)mania symptoms (ASRM) (N=44)

	ASRM Items and total score						
ActivPAL3 totalled SB variables: N=44	**Happiness**	**Confidence**	**Sleep**	**Talking**	**Activity**	**Total score**	**Number of significant correlations**
Time spent in SB (hrs)	*0.411***	*0.516****	-0.030	*0.640****	*0.366***	*0.552****	5
Number of SB bouts	0.013	0.002	-0.014	-0.062	0.045	-0.026	0
Number of SB bouts lasting 0-30mins	-0.019	-0.027	0.012	-0.102	0.048	-0.063	0
Time spent in SB bouts lasting 0-30mins (hrs)	0.045	0.181	-0.053	0.187	0.140	0.096	0
Number of SB bouts lasting 30-60mins	0.117	0.250	-0.273	*0.314**	0.135	0.180	1
Time spent in SB bouts lasting 30-60mins (hrs)	0.114	0.235	-0.283	0.289	0.114	0.163	0
Number of SB bouts lasting 60-120mins	0.282	*0.308**	-0.089	0.286	0.152	*0.350**	2
Time spent in SB bouts lasting 60-120mins (hrs)	0.280	*0.313**	-0.078	0.284	0.164	*0.354***	2
Number of SB bouts lasting over 120mins	0.145	0.055	0.021	*0.330**	0.029	0.234	1
Time spent in SB bouts lasting over 120mins (hrs)	0.151	0.049	0.091	*0.329**	0.040	0.241	1

**p<0.05, **p<0.01, ***p<0.001*

Table 5.14 shows that three SB variables; ‘time spent in SB,’ ‘number of SB bouts lasting 60-120mins’ and ‘time spent in SB bouts lasting 60-120mins’ showed positive associations of medium strength with the total score for (hypo)mania. ‘Time spent in SB bouts’ was positively associated with all items except ‘needing less sleep than usual’. ‘Talking more than usual’ showed the strongest association observed, a strong positive association with ‘time spent in SB.’

From Table 5.13 and 5.14, ‘talking more than usual’ showed the most significant correlations with PA and SB variables compared to other mood symptoms (N=6).

5.5.6 Identifying potential confounding factors in the relationships between physical activity, sedentary behaviour & self-reported mood symptoms

Aim 1, objective 5: To identify potential confounding factors in the relationships between device-measured PA, SB, and self-reported BD mood symptoms.

The variables presented in the participant description section were explored further to identify if there were any significant differences between grouping variables *(gender, BD sub-type, medication and physical health co-morbidities)* as well as any associations between continuous variables *(age, BMI, age of BD illness onset (yrs), length of BD illness (yrs), average number of (hypo)manic episodes per illness year, and average number of depressive episodes per illness year)* with the device-measured PA and SB, and the self-reported mood symptoms. This was done to explore whether any significant associations identified in sections 5.5.4 to 5.5.5 could be explained by these factors. Due to the number of variables and analyses carried out, this section presents the analyses of factors which were identified as potential confounding factors. All other analyses including non-significant analyses, and analyses which only showed a significant difference/association with either PA, SB or mood (and therefore were not considered to be confounding factors) are presented in Appendix P.

Gender

Significant differences were identified between males and females for PA and mood variables (see Table 5.15 below).

Table 5.15 Significant differences between genders for PA & mood variables

PA & mood variables	Differences between males & females (mean±SD)
Number of steps taken	t(49)=2.05* M= 4531 (±1991.20) F= 3493 (±1522.19)
Time spent in MVPA (hrs)	t(49)=2.57** M= 1.20(±0.54) F= 0.86 (±0.39)
Energetic	U=130.50** M: Md= 3.00 (IQR: 2.00, 4.75) F: Md= 2.00 (IQR: 1.00, 3.00)
Elation	U=169.50** M: Md=2.00, (IQR: 1.00, 4.00) F: Md=1.00, (IQR: 1.00, 2.00)

M= male participants, F= female participants
**p<0.05 **p<0.01, ***p<0.001*

Table 5.15 above shows that males took significantly more steps, engaged in more time in MVPA, and also reported higher self-ratings of 'energetic' and 'elation' than females.

Given the identified significant differences between males and females on both PA engagement ('time spent in MVPA,' and 'number of steps taken') and also mood ('energetic' and 'elated'), it was considered that gender may be a confounding factor in the analysis presented in Table 5.8 (page 231) which showed a significant relationship between the number of steps taken with elation and energy, and also time spent in MVPA and elation and energy. These relationships are therefore presented below in Table 5.16 separately for males and females to explore if gender was a confounding factor.

Table 5.16 Correlations between PA variables & feeling 'energetic' split by gender

	Gender	
	Males (N=108)	**Females (N=234)**
Time spent in MVPA (hrs) & energetic	0.186	0.209**
Time spent in MVPA (hrs) & elation	0.000	0.209**
Number of steps taken & energetic	0.216*	0.218**
Number of steps taken & elation	0.005	0.218**

**p<0.05 **p<0.01, ***p<0.001*

Table 5.16 above shows that the small strength positive association between the daily number of steps taken and feeling 'energetic' was similar for both males and females, and so gender was not a confounding factor in this relationship. However, the small strength positive associations observed between daily time spent in MVPA and energetic, daily time spent in MVPA and elation, and daily number of steps taken and elation, were only significant for female participants. This indicates that gender was a confounding factor in these relationships.

Medication

Anti-depressants

Significant differences of anti-depressant use for SB and (hypo)mania total symptom severity were identified (see Table 5.17 below)

Table 5.17 Significant differences of anti-depressant use on SB & mood variables

SB & mood variables	Differences between those using & not using anti-depressants (mean±SD)
Time spent in SB (hrs)	t(39)=-3.75** Y= mean=10.67(±1.55) N= mean=8.94(±1.35)
Number of SB bouts lasting 60-120mins	t(36.75)=-3.43** Y= mean=2.15(±0.80) N= mean=1.28(±0.80)
Time spent in SB bouts lasting 60-120mins (hrs)	t(39)=-3.58** Y= mean=2.90(±1.06 N= mean=1.71(±1.06)
Number of SB bouts lasting 120+ mins	U=125.50* Y= Md=0.29, IQR=0.14, 0.52 N= Md=0.14, IQR=0.00, 0.29
Time spent in SB bouts lasting 120+ mins (hrs)	U=113.00** Y= Md=0.85, IQR=0.46, 1.16 N= Md=0.35, IQR=0.00, 0.66
ASRM ((hypo)mania) total score	U=107.00** Y= Md=3.00, IQR=I.00, 4.75 N= Md=0.00, IQR=0.00, 2.00

Y=participants self-reporting anti-depressant use, N= participants not reporting anti-depressant use
**p<0.05 **p<0.01, ***p<0.001*

Table 5.17 above shows participants self-reporting using anti-depressants spent significantly more time sedentary, and more time in sedentary bouts lasting 60-120mins, and over 120mins (aswell as a greater number of sedentary bouts lasting 60-120mins and over 120mins), than those not reporting use. Participants reporting the use of anti-depressants also scored significantly higher on the ASRM, and so were experiencing greater symptom severity for (hypo)mania.

Given the identified significant differences between those using and not using anti-depressants on their SB ('time spent in SB,' the 'number of SB bouts lasting 60-120mins' and 'number of SB bouts lasting over 120mins,' and 'time spent in SB

bouts lasting over 120mins') and also mood (total ASRM score for (hypo)mania), it was considered that anti-depressant use may be a confounding factor in the analysis presented in Table 5.14 (page 241) which showed significant relationships between time spent in SB, as well as the number and time spent in bouts lasting 60-120mins, and over 120mins, and (hypo)mania (total ASRM score). These relationships are presented below in Table 5.18 separately by those using and not using anti-depressants to explore whether the use of anti-depressants was a confounding factor.

Table 5.18 Correlations between SB & (hypo)mania (ASRM) split by anti-depressant use

	Anti-depressant use	
	Yes (N=15)	**No (N=20)**
Time spent in SB (hrs) & ASRM	*0.603**	0.255
Number of SB bouts lasting 60-120mins & ASRM	0.421	0.045
Time spent in SB bouts lasting 60-120mins (hrs) & ASRM	0.432	0.060
Number of SB bouts lasting 120+ mins & ASRM	-0.038	0.174
Time spent in SB bouts lasting 120+ mins & ASRM	-0.144	0.572

**p<0.05, **p<0.01, ***p<0.001*

Table 5.18 above shows a strong, positive association between time spent in SB and the total ASRM score for (hypo)mania for those using anti-depressants, with no other significant associations between SB and (hypo)mania. The use of anti-depressants was therefore a confounding factor in the relationship between time spent in SB, and the ASRM total score for (hypo)mania.

Body Mass Index

Relationships between BMI and PA, SB and feeling 'energetic' were identified (see Table 5.19 below).

Table 5.19 Correlations between BMI & PA, SB & mood variables

PA, SB & mood variables (N=44)	BMI
Time spent stepping (hrs)	-0.418**
Number of steps	-0.428**
Time spent in light PA (hrs)	-0.362*
Time spent in MVPA (hrs)	-0.418**
Time spent in SB (hrs)	0.322*
Number of SB bouts lasting 120+ mins	0.300*
Time spent in SB bouts lasting 120+ mins (hrs)	0.314*
Energetic	-0.369**

**p<0.05 **p<0.01, ***p<0.001*

Table 5.19 above shows a negative association between BMI and PA variables ('time spent stepping', the 'number of steps taken', 'time spent in light PA' and 'time spent in MVPA'), as well as a negative association between BMI and feeling 'energetic', i.e. participants with a higher BMI reported feeling less energetic and engaged in less PA than those with lower BMIs. Table 5.19 also shows that BMI was positively associated with time spent in SB (the number of SB bouts lasting over 120mins, as well as time spent in SB bouts lasting over 120mins), ie. participants with higher BMIs spent more time sedentary than those with lower BMIs.

Given the identified significant negative associations between BMI and PA variables ('time spent stepping,' 'number of steps taken,' 'time spent in light PA,' and 'time spent in MVPA') and between BMI and feeling 'energetic', it was considered that BMI

may have been a confounding factor in the analysis presented in Table 5.8 (page 231) which showed significant relationships between the number of steps taken, time spent stepping, time spent in light PA and time spent in MVPA and feeling 'energetic'. These relationships are presented below in Table 5.20 by BMI category to explore if BMI was a confounding factor (the underweight category was removed from this analysis as only 2% of participants were in this group).

Table 5.20 Correlations between PA variables & feeling energetic split by BMI category

	BMI Categories		
	Normal (N=87)	**Pre-obese (N=55)**	**Obese (N=146)**
Time spent stepping (hrs) & energetic	0.040	*0.269**	*0.457**
Number of steps taken & energetic	0.099	*0.306**	*0.480***
Time spent in light PA (hrs) & energetic	-0.057	0.134	*0.315**
Time spent in MVPA (hrs) & energetic	0.108	*0.306**	*0.472***

**p<0.05 **p<0.01, ***p<0.001*

Table 5.20 above shows that the positive association between PA variables (time spent 'stepping' 'number of steps taken' 'time spent in light PA' and 'time spent in MVPA') and feeling 'energetic' was stronger in 'obese' participants (medium strength) than 'pre-obese' participants (small-medium strength). These associations were not significant in participants with a 'normal' BMI, and so BMI is a confounding factor in the relationship between PA (time spent 'stepping' 'number of steps taken' 'time spent in light PA' and 'time spent in MVPA') and feeling 'energetic.'

Given the identified significant positive associations between BMI and SB ('time spent in SB,' 'number of SB bouts lasting over 120mins,' and 'time spent in SB bouts

lasting over 120mins') and feeling 'energetic,' Table 5.21 below presents the association between SB and 'energetic' by BMI category to explore whether BMI was a confounding factor in the analysis presented in Table 5.9 (page 232) (again the underweight category was removed from this analysis as only 2% of participants were in this group).

Table 5.21 Correlations between SB variables & feeling energetic, split by BMI category

	BMI Categories		
	Normal (N=87)	**Pre-obese (N=55)**	**Obese (N=146)**
Time spent in SB (hrs) & energetic	0.131	-0.330*	-0.313***
Number of SB bouts lasting 120+ mins & energetic	0.355**	0.288*	-0.300***
Time spent in SB bouts lasting 120+ mins (hrs) & energetic	0.353**	0.289*	-0.281**

**p<0.05, **p<0.01, ***p<0.001*

Table 5.21 above shows negative, medium strength associations between time spent in SB and feeling energetic in those whose BMI was 'pre-obese' or 'obese' only. Positive, medium strength associations of SB bouts lasting over 120mins and feeling energetic are observed for those with a 'normal' or 'pre-obese' BMI, and negative, medium strength associations in those with an 'obese' BMI. Table 5.21 shows that BMI was a confounding factor in the relationship between time spent in SB and feeling 'energetic' and that the relationship between the number of SB bouts lasting over 120mins, and time spent in SB bouts over 120mins and feeling 'energetic' is different between those with a 'normal' and pre-obese BMI (positive) and 'obese' BMI (negative).

Lifetime psychiatric history

Length of bipolar disorder illness (yrs)

Positive associations between length of BD illness (yrs) and PA and feeling 'energetic' were identified (see Table 5.22 below).

Table 5.222 Significant correlations between length of BD illness onset & PA & mood variables

PA and mood variables (N=49)	Length of BD illness (yrs)
Time spent standing (hrs)	0.300*
Time spent in light PA (hrs)	0.337*
Energetic	0.287*

**p<0.05 **p<0.01, ***p<0.001*

Table 5.22 above shows significant, positive associations between the length of BD illness (yrs) and time spent standing and time spent in light PA, as well as feeling energetic, i.e. participants who had lived with BD for longer spent more time standing, more time in light PA, and reported feeling more energetic, than those with a shorter illness duration.

Given the identified positive associations between length of BD illness (yrs) and PA variables ('time spent standing' and 'time spent in light PA') and also feeling 'energetic,' it was considered that the length of BD illness (yrs) may have been a confounding factor in the analysis presented in Table 5.8 (page 231) which showed significant relationships between time spent standing and time spent in light PA with feeling 'energetic'. These relationships are presented below in Table 5.23 by the length of BD illness (yrs) to explore whether this was a confounding factor (grouped by periods of 15yrs: age range/3).

Table 5.23 Correlations between PA variables & feeling 'energetic' split by length of BD illness (yrs)

	Length of BD illness (yrs)		
	7- 22 (N=91)	**23 – 37 (N=130)**	**38+ (N=110)**
Time spent standing (hrs) & energetic	0.012	*0.431***	*0.222**
Time spent in light PA (hrs) & energetic	0.020	*0.203**	*0.212**

**p<0.05 **p<0.01, ***p<0.001*

Table 5.23 above shows a medium strength positive association between time spent standing and feeling energetic in participants who had lived with BD for between 23-37yrs, and a small strength positive association for those who had lived with BD for over 38yrs. Table 5.23 also shows that the positive association of 'time spent standing' and 'time spent in light PA' with feeling energetic was only significant in those who had lived with BD for longer than 23yrs, and so the length of BD illness onset (yrs) was a confounding factor in the relationship between time spent standing and time spent in light PA with feeling 'energetic.'

5.5.7 Exploring the validity of the Marshall Sitting Questionnaire in people living with bipolar disorder

Aim 2, objective 1: To calculate weekday, weekend day, average day and total week self-reported sitting time and report on the sitting behaviours of people living with BD using the MSQ.

Aim 2, objective 2: To explore the validity of the MSQ as a self-report 7-day recall tool in BD by comparing weekday, weekend-day, average day, and total week self-reported sitting time against device-measured weekday, weekend-day, average day, and total week time spent in SB from an ActivPAL3.

Weekday analyses

Time spent sitting (hrs) in the various domains of the MSQ for an average weekday are shown in Figure 5.12 below (N=44, 86.27%).

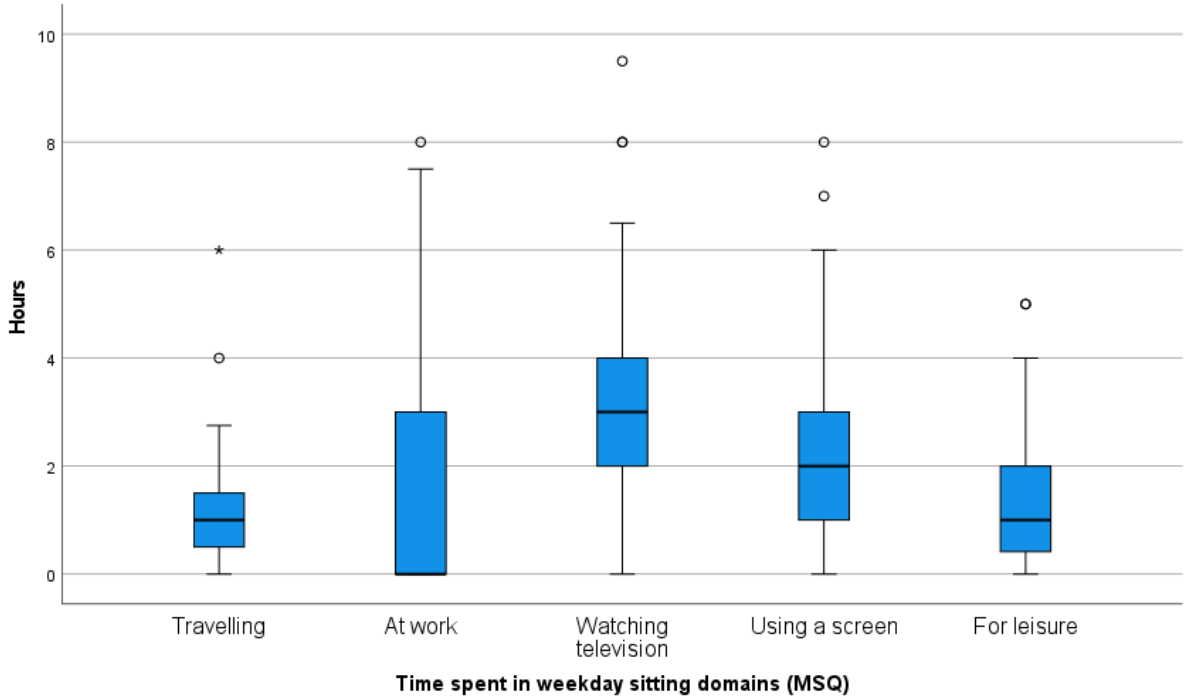


Figure 5.12 Distribution of self-reported MSQ time spent in sitting domains on an average weekday (N=44)

Figure 5.12 shows that on an average weekday during the study period, participants self-reported spending most time sitting watching television (*Md*=3.00 *IQR*=2.00, 4.00), followed by other screen time (*Md*=2.00 *IQR*=1.00, 3.00). Less time sitting was spent in leisure (*Md*=1.00 *IQR*=0.37, 2.00) and for travelling (*Md*=1.00 *IQR*=0.50, 1.50), and the least amount of time was spent sitting at work (*Md*=0.00 *IQR*=0.00, 3.00). Sitting at work showed the greatest variation between participants. Travelling showed the least variation.

The total time spent sitting on an average weekday according to the ActivPAL3 was 10.00hrs (±1.80) with a range of 6.82-14.21. The total time spent sitting on an average weekday according to the self-reported MSQ was 9.42hrs (±3.21) with a range of 3.00-16.50. The MSQ therefore reported time spent in SB as being 34.80mins less than the ActivPAL3 for the average weekday. Using paired samples t-tests, the difference between these two measures was not significant ($t(43)=-0.992$, $p=0.327$).

The relationship between the MSQ (self-reported) total sitting time (hrs) and ActivPAL3 time spent in SB (hrs) on an average weekday is presented in Figure 5.13 below (N=44, 86.27%).

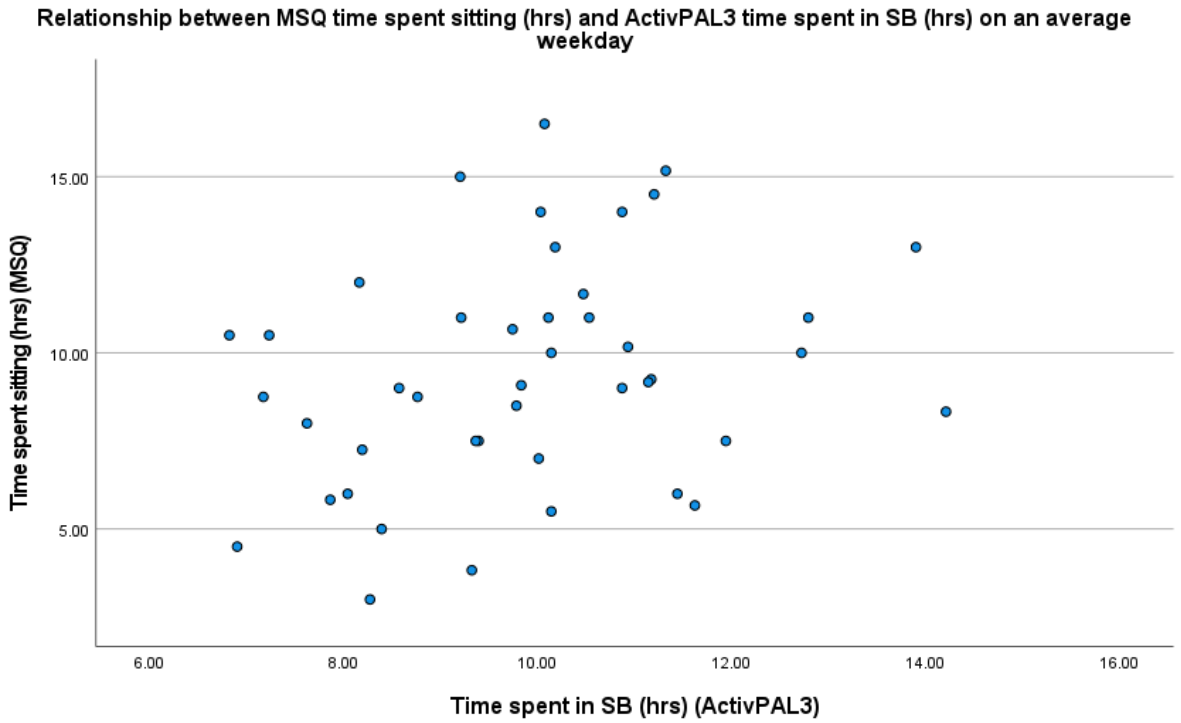


Figure 5.13 Relationship between two measures: MSQ sitting time & ActivPAL3 time spent in SB on an average weekday (N=44)

Figure 5.13 shows a weak, positive relationship between totalled sitting time for the average weekday using the MSQ (during the 7-day period), and the average time spent in SB (hrs) on a weekday as measured by the ActivPAL3. Pearson's parametric correlation showed this relationship to border on significance (r=0.283, n=44, p=0.063).

To assess the agreement between the average weekday sitting time as estimated by participants self-reporting using the MSQ, and the average weekday time spent in

SB (hrs) as measured by the ActivPAL3, a Bland-Altman plot (Bland & Altman, 1986) was created (Figure 5.14) to plot the difference of the two measures, against the mean of the two measures (N=44).

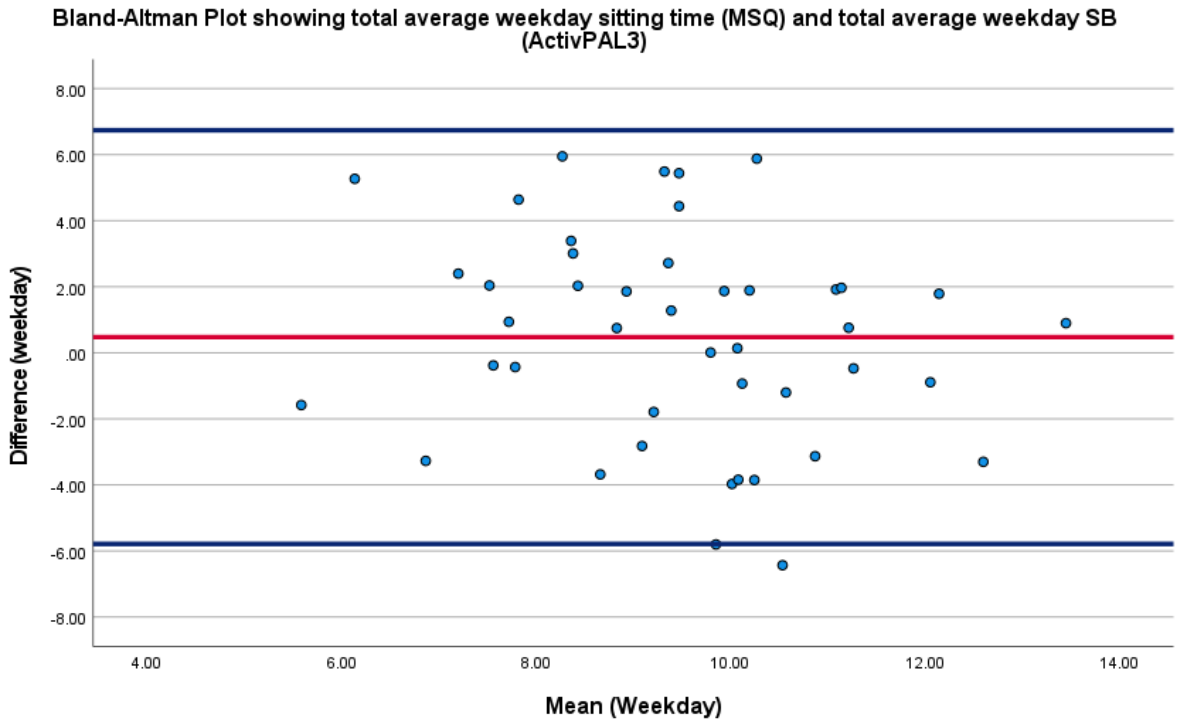


Figure 5.14 Bland-Altman plot showing agreement between two measures: weekday sitting time (MSQ) & weekday SB (ActivPAL3) (N=44)

In Figure 5.14, the red line represents the overall mean, (mean= 0.48(±3.20)) and the blue lines represent the limits of agreement (LoA): (upper= 6.74, lower= -5.78). The points on Figure 5.14 are scattered all over the graph, which indicates that there is no consistent bias between the ActivPAL3 or MSQ measure. All points except one in Figure 5.14 are within the LoA of the plot, indicating overall agreement between the measures.

To further assess agreement between weekday MSQ and ActivPAL3 measures of SB time (hrs), a linear regression was carried out using the difference of the two measures and the mean of the two measures which was non-significant ($F=1.920(1,42)$, $p=0.173$), indicating there was no proportional bias between the two measures (adjusted r-square=0.021, beta=-0.400).

Weekend day analyses

Time spent sitting (hrs) in the various domains of the MSQ (self-reported) for an average weekend day are shown in Figure 5.15 below (N=42, 82.35%).

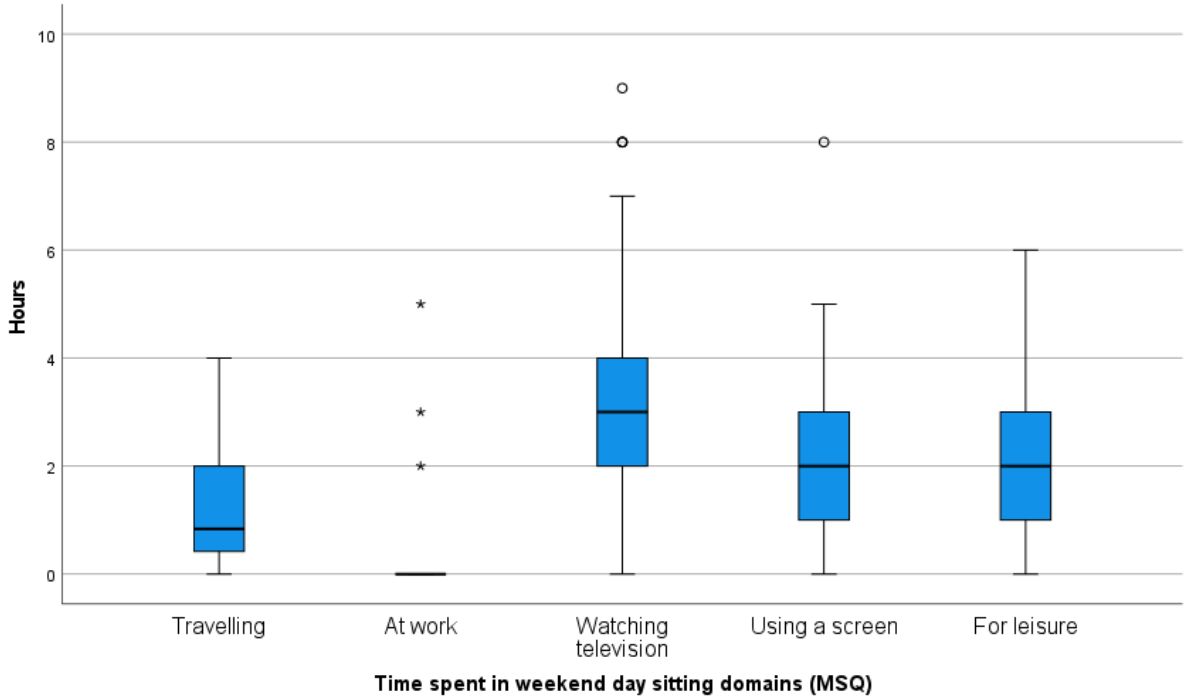


Figure 5.15 Distribution of time spent in sitting domains on an average weekend day (N=42)

Figure 5.15 shows that on an average weekend day during the study period, participants self-reported spending most of their time sitting watching television (*Md*=3.00 *IQR*=2.00, 4.25), followed by leisure (*Md*=2.00 *IQR*=1.00, 3.00), and other screen time (*Md*=2.00 *IQR*=1.00, 3.00). Less time sitting was spent for travel (*Md*=0.84 *IQR*=0.38, 2.00) and the least amount of time spent sitting was at work (*Md*=0.00 *IQR*=0.00, 0.00).

The total time spent sitting on an average weekend day according to the ActivPAL3 was 9.80hrs (±2.21) with a range of 5.28-14.17. The total time spent sitting on an average weekend day according to the self-reported MSQ was 9.04hrs (±2.54) with a range of 4.00-14.00. The MSQ therefore reported time spent in SB as being 45.60mins less than the ActivPAL3 for the average weekend day. Using paired samples t-tests, the difference between these two measures was not significant ($t(41)=-1.228$, $p=0.226$).

Participants spent slightly more time sitting on an average weekday than an average weekend day. Using a paired samples t-tests, this difference was also not significant ($t(39)=1.18$, $p=0.244$).

The relationship between the MSQ (self-reported) time spent sitting (hrs) and ActivPAL3 time spent in SB (hrs) on an average weekend day is presented in Figure 5.16 below (N=42, 82.35%).

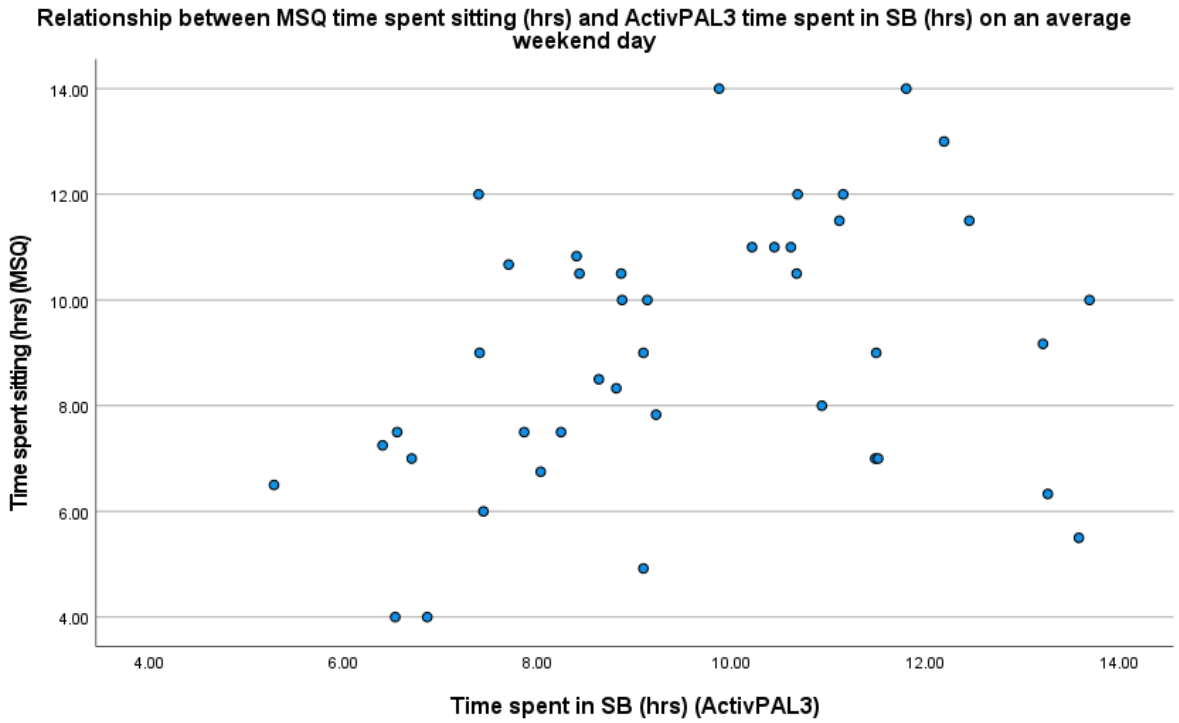


Figure 5.16 Relationship between two measures: MSQ sitting time & ActivPAL3 SB on an average weekend day (N=42)

Figure 5.16 shows a moderate, positive relationship between totalled sitting time for the average weekend day during the 7-day period, and the average time spent in SB (hrs) on a weekend day as measured by the ActivPAL3. Pearson's parametric correlation showed this relationship to be significant and of medium strength (r=0.344, n=42, p=0.026).

To assess the agreement between the average weekend day sitting time as estimated by participants using the MSQ (self-reported), and the average weekend day time spent in SB (hrs) as measured by the ActivPAL3, a Bland-Altman plot (Bland & Altman, 1986) was created to plot the difference of the two measures, against the mean of the two measures (N=42).

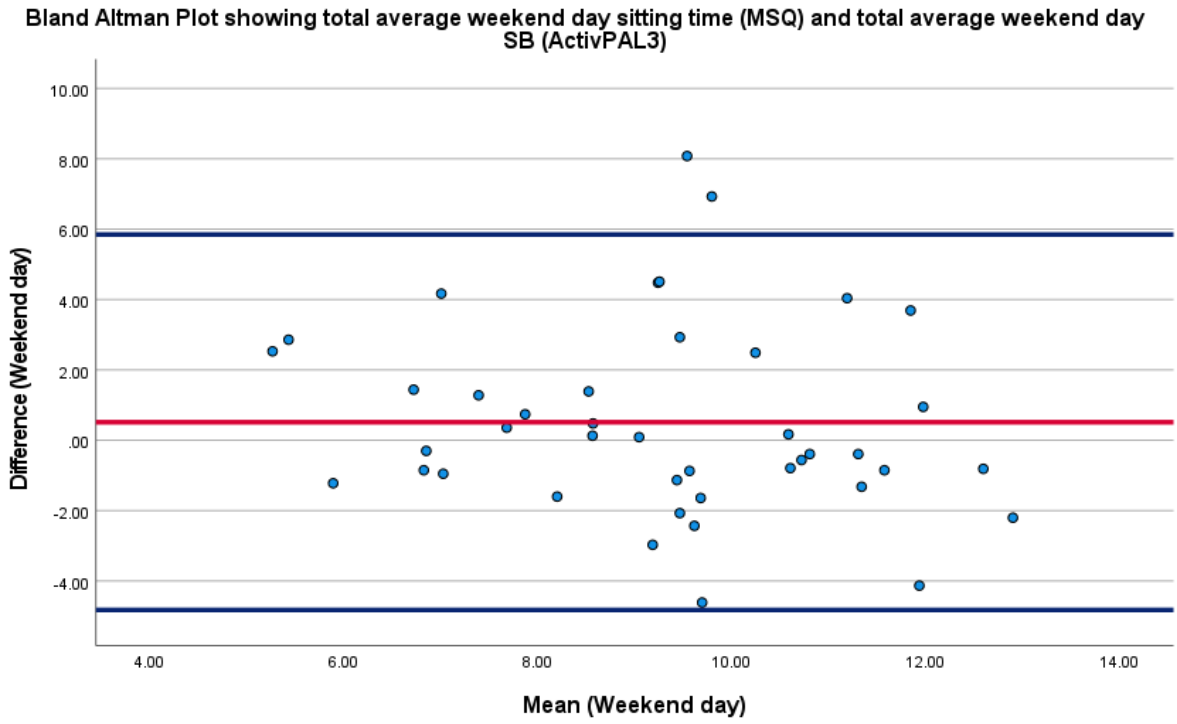


Figure 5.17 Bland-Altman plot showing levels of agreement between two measures: weekend day sitting time (MSQ) & weekend day SB (ActivPAL3) (N=42)

In Figure 5.17 the red line represents the overall mean (0.52(±2.72)) and the blue lines represent the LoA: (upper=5.85, lower=-4.82). Although the points on Figure 5.17 are scattered all over the graph, there are more points which fall below the mean line (red). All points except two in Figure 5.17 are within the LoA on the plot, indicating agreement between the measures.

To further assess agreement between weekend day MSQ and ActivPAL3 measures of SB time (hrs), a linear regression was carried out using the difference of the two measures and the mean of the two measures which was non-significant ($F=1.046(1, 40)$, $p=0.313$)) indicating overall that there was no proportional bias between the two measures (adjusted r-squared=0.001, beta=-0.224).

Average day

The total time spent sitting on an average day according to the ActivPAL3 was 9.93hrs (±1.74) with a range of 6.67-14.00. The total time spent sitting on an average day according to the self-reported MSQ was 9.14hrs (±2.87) with a range of 3.29-14.93. The MSQ therefore reported time spent in SB as being 47.40mins less than the ActivPAL3. Using paired samples t-tests, the difference between these two measures was not significant (t(40)=-1.384, p=0.174).

The relationship between the MSQ (self-reported) total sitting time on the average day (hrs) and ActivPAL3 time spent in SB (hrs) on an average day is presented in Figure 5.18 below (N=41, 80.39%).

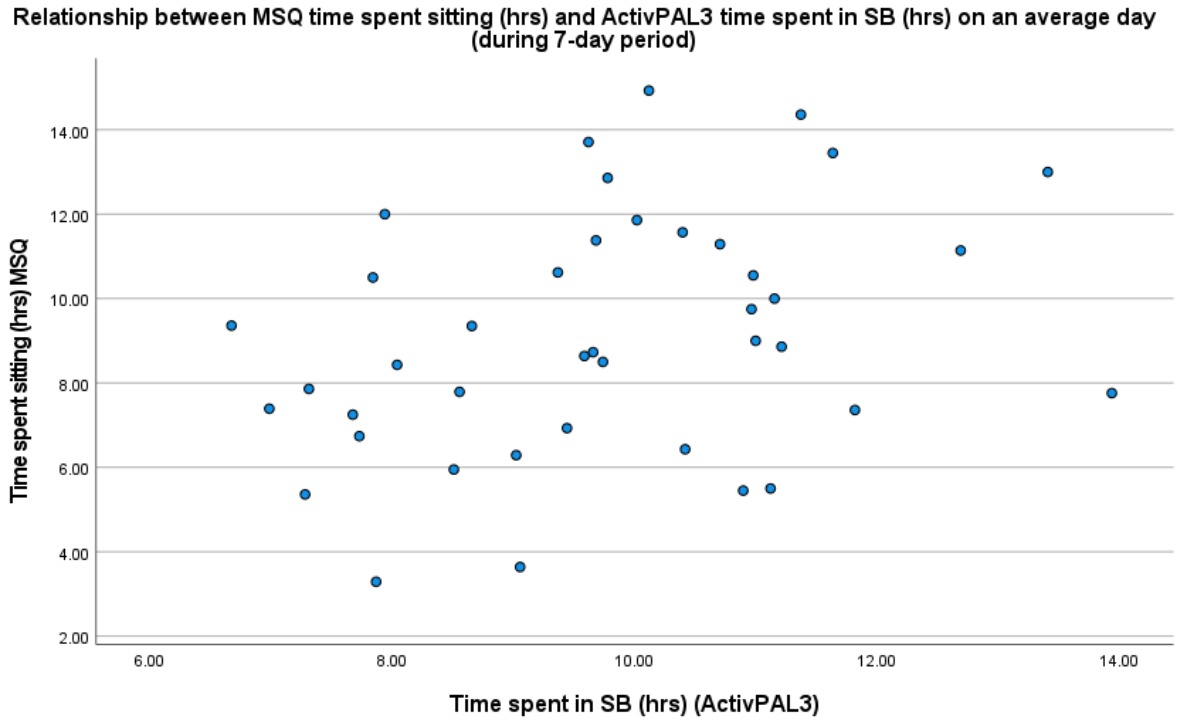


Figure 5.18 Relationship between two measures: MSQ sitting time & ActivPAL3 SB on an average day (N=41)

Figure 5.18 shows a moderate, positive relationship between totalled sitting time on an average day using the MSQ (during the 7-day period) and the average time spent in SB (hrs) on an average day as measured by the ActivPAL3. Pearson's parametric correlation showed this relationship to be significant and of medium strength (r=0.333, n=41, p=0.033).

To assess the agreement between the average day sitting time as estimated by participants self-reporting using the MSQ, and the average day time spent in SB (hrs) as measured by the ActivPAL3, a Bland-Altman plot (Bland & Altman, 1986) was created (Figure 5.19) to plot the difference of the two measures, against the mean of the two measures (N=41).

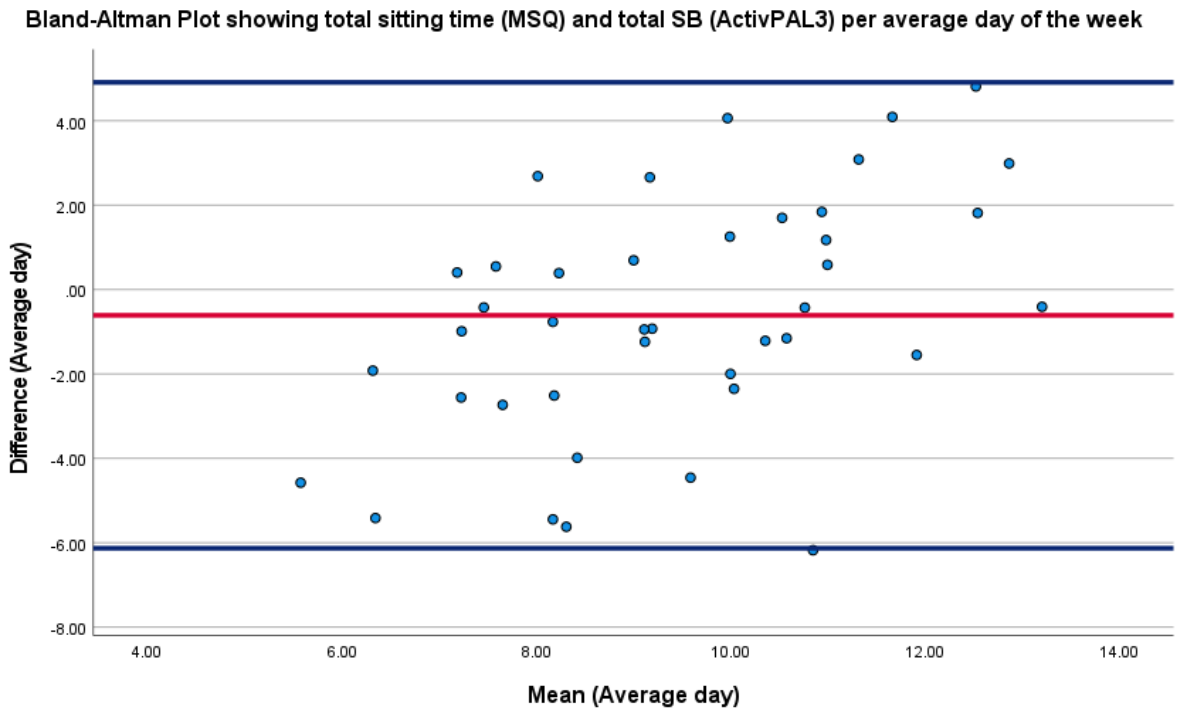


Figure 5.19 Bland-Altman plot showing agreement between two measures: average day sitting time (MSQ) & average day SB (ActivPAL3) (N=41) (average for the whole week)

In Figure 5.19, the red line represents the overall mean (mean=-0.61(±2.82)) and the blue lines represent the LoA (upper=4.91, lower=-6.13). The points on Figure 5.19 are all within the LoA, however trend upwards indicating a positive relationship between the difference and mean of the two measures.

To further assess agreement between average day self-reported MSQ sitting time, and average ActivPAL3 time spent in SB (hrs), a linear regression was carried out using the difference between the two measures and the mean of the two measures which was significant (F=12.144(1,39), p=0.001), indicating there was a proportional bias between the two measures (adjusted r-square=0.218, beta=0.487).

Total week

The total time spent sitting for the week (7-day period) according the ActivPAL3 was 67.45hrs (±12.59) with a range of 46.71-97.55. The total time spent sitting according to the self-reported MSQ was 61.60hrs (±19.03) with a range of 23.00-100.50. The MSQ therefore reported time spent in SB as being 5.85hrs less than the ActivPAL3 for the week. Using paired samples t-tests, the difference between these two measures was not significant (t(36)=1.842, p=0.074).

The relationship between the MSQ (self-reported) total time spent sitting (hrs) and ActivPAL3 time spent in SB (hrs) for the week (7-day period) is presented in Figure 5.20 below (N=37, 72.55%).

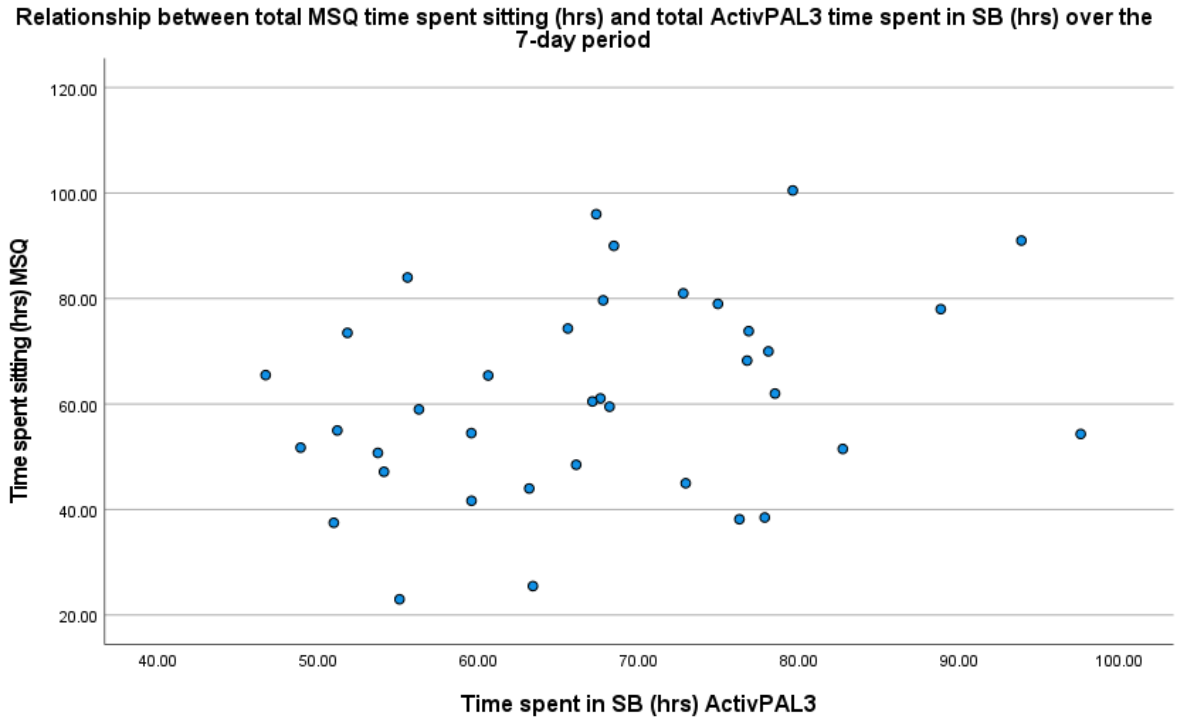


Figure 5.20 Relationship between two measures: MSQ sitting time & ActivPAL3 time in SB for the total week (N=37)

Figure 5.20 shows a medium strength, positive relationship between totalled sitting time for the week (7-day period), and the time spent in SB (hrs) for the week as measured by the ActivPAL3. Pearson's parametric correlation showed this relationship to be non-significant (r=0.305, n=37, p=0.067).

To assess the agreement between the total week (7-day period) sitting time as estimated by participants using the MSQ (self-reported), and total week time spent in SB (hrs) as measured by the ActivPAL3, a Bland-Altman plot (Bland & Altman, 1986) was created to plot the difference of the two measures, against the mean of the two measures (N=37).

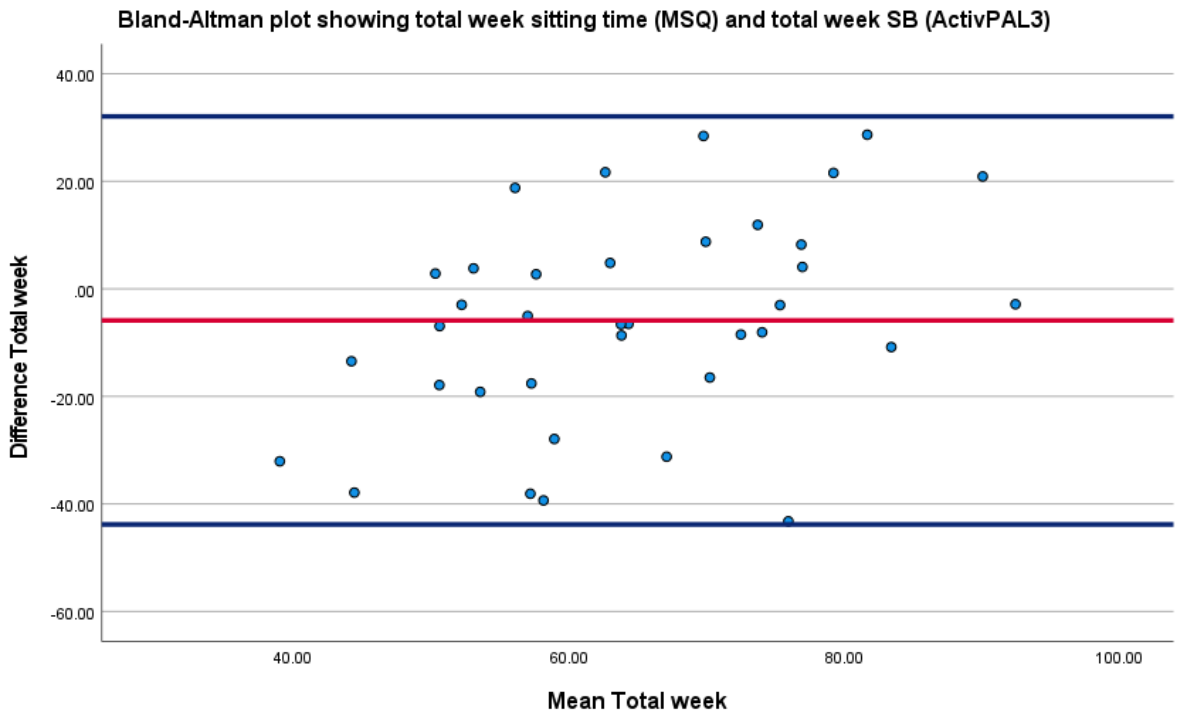


Figure 5.21 Bland-Altman plot showing levels of agreement between two measures: total week sitting time (MSQ) and total week SB (ActivPAL3) (N=37)

In Figure 5.21 the red line represents the overall mean (-5.86(±19.36)) and the blue lines represent the LoA: (upper=32.08, lower=-43.80). All points in Figure 5.21 are within the LoA on the plot, however trend upwards indicating a positive relationship between the difference and mean of the two measures.

To further assess agreement between total week (7-day period) MSQ and ActivPAL3 measures of SB time (hrs), a linear regression was carried out using the difference of the two measures and the mean of the two measures which was significant (F=6.97(1, 35), p=0.012)) indicating a level of proportional bias between the two measures (adjusted r-squared=0.142, beta=0.408).

5.5.7.1 Relationships between self-reported sitting time & self-reported mood compared with device-measured sedentary behaviour

Aim 2, objective 3: To compare the relationships between self-reported 7-day recall total week sitting time (MSQ) and self-reported 7-day recall mood, to those found using device-measured SB from an ActivPAL3.

Table 5.24 below presents the relationship between self-reported time spent sitting (MSQ) and device-measured SB (ActivPAL3) with self-reported depression (QIDS) and (hypo)mania (ASRM).

Table 5.234 Comparing relationships between total week self-reported time spent sitting (MSQ) & device-measured SB with self-reported mood

Sedentary Behaviour Measure:	**ASRM total score ((hypo)mania)**	**QIDS total score (depression)**
Total week (MSQ) (N=41)	-0.109	0.052
Total week (ActivPAL3) (N=44)	*0.552***	0.119

**p<0.05, **p<0.01, ***p<0.001*

Table 5.24 above shows a significant positive correlation between ActivPAL3 measured SB with (hypo)mania, of strong strength, and no significant associations between self-reported sitting time (MSQ) and mood.

5.5.8 Results summary

This study has provided some important results for understanding the relationships between PA, SB, and BD mood symptoms. The key results have been summarised below:

- Overall participants spent more time on average per day in SB (10hrs) than in PA. However, there was a wide range between this average (7hrs 20mins) indicating high variability between participants.
- Overall participants spent more time on average per day standing (4hrs) than stepping/walking (1hr 40mins), and more time in MVPA (60mins) than in light PA (40mins).
- For daily PA and mood symptoms (MZ) significant positive associations were observed between PA: 'time spent stepping', 'time spent standing', 'time spent in MVPA' and 'time spent in light PA', with *'elation'* and *'energetic,'* (in females only) and negative associations were observed with *'sadness.'*
- For daily SB and mood symptoms (MZ) a significant negative association was observed between 'time spent in SB' and *'energetic.'*
- For weekly PA, SB and 7-day recall (hypo)mania symptoms (ASRM) 'time spent stepping' and 'time spent in light PA' were negatively associated with *'talking,'* and 'time spent in SB' was positively associated with ASRM items *(happiness, confidence, talking, activity)* and the ASRM total score (in those using anti-depressants only).
- For weekly PA, SB and 7-day recall depression symptoms (QIDS), all PA variables which showed significant associations with mood symptoms were

negative associations, and all SB variables which showed significant correlations were positive associations.

- There were more significant associations between daily PA, SB, and mood symptoms (MZ) than weekly PA, SB and mood symptom severity (QIDS & ASRM).
- Gender, BMI, and the length of BD illness (yrs) are potential confounding factors in the relationship between PA and mood.
- The use of anti-depressants and BMI are potential confounding factors in the relationship between SB and mood.
- Participants self-reporting their time spent sitting using the MSQ reported spending more time watching television than the other MSQ domains regardless of whether this was on a weekday or weekend day.
- The MSQ demonstrated acceptable agreement to the ActivPAL3, however underestimated SB by approximately 47mins per day at the group level (6hrs per week).

5.6 Discussion

This section discusses the results of this study, and then reflects on the study's strengths and limitations. A full synthesis of the results from all three studies is provided in the discussion chapter, chapter seven.

The current study found that participants spent the majority of their time in SB, which is consistent with previous studies exploring SB in BD (Janney et al., 2014; Vancampfort et al., 2016a; 2017b). The current study found total time spent in SB to be on average 10hrs a day. Vancampfort et al., (2016a) reported people with BD spending on average 10hrs 13mins per day in SB in their systematic review which included six studies totalling 279 people with BD, and Vancampfort et al., (2017b) reported 10hrs 15mins which are both consistent with the current study's findings. Janney et al., (2014) however reported participants spending considerably more time in SB (13hrs 30mins) when measured with an Actigraph.

Furthermore, despite concluding people with BD were more sedentary compared to those living with schizophrenia or major depressive disorder (MDD), Vancampfort et al., (2017b) also found that people living with BD engaged in significantly more MVPA per day than those with schizophrenia or MDD (1hr 22mins per day, 9hrs 35mins per week) in their systematic review which explored PA and SB levels. This supports the current study's results, which found participants spent more time in MVPA than in light PA on average per day (1hr per day), although the time spent in MVPA was less than that in Vancampfort et al., (2017b). However, Janney et al., (2014) reported that none of their 60 BD participants met the CMO guidelines of 75mins vigorous-150mins moderate intensity PA per week. Vancampfort et al., (2017b) also found that lower PA levels were associated with being male, having a

higher BMI, using antidepressant medication, and a longer illness duration. The current study also found associations between these variables, but found that males engaged in more MVPA than females (however the relationship between MVPA and 'elation' and 'energy' only being significant in females); and that a longer illness duration was positively associated with PA. In contrast to Vancampfort et al., (2017b), employment status, education, and relationship status were not collected in this study.

Merikangas et al., (2018) had previously used Actiwatches to assess the associations among energy, sleep, mood, and motor activity in 54 participants with BD. Mood and energy were subjectively self-reported by participants four times a day and associations were made with the Actiwatch data collected between these time points using a cross-lagged design for time-series analysis. The results identified unidirectional associations of symptoms of depression and motor activity, and bidirectional relationships of feeling energetic and motor activity. It was recommended that BD interventions target subjective energy levels and activity rather than solely focussing on mood, and to take into consideration the pharmacological effects of medication, as well as factors affecting motor activity, such as the time of day. Merikangas et al., (2018) also found positive associations of activity and energy, and negative associations of activity and sadness using an Ecological Momentary Assessment which is supportive of the current study's results which also found positive associations between daily ratings of feeling 'energetic' with MVPA in females, and negative associations between feeling 'sad' and MVPA. Future research should continue this exploration using a larger sample and longitudinal design which would offer a better opportunity to explore the daily temporality of activity and mood.

Since the completion of this study, there has been a recent surge in published explorations using accelerometery as a device-based measure of PA/SB in people living with BD (Burgess, Bradley, Anderson, Gallagher, & Mcallister-williams, 2020; Knapen et al., 2020; Krane-Gartiser et al., 2019; McGowan, Goodwin, Bilderbeck, & Saunders, 2020; Melo et al., 2019). Krane-Gartiser et al., (2019) used actigraphy for the purpose of exploring sleep-wake cycles in BD rather than aiming to explore PA or SB. Knapen et al., (2020) explored biomarkers of activity in 106 BD patients, with 14 participating in a longitudinal monitoring. The study found that high symptom severity for depression (Inventory of Depressive Symptoms) one week predicted lower activity the next, with a lag of 5-7 days. Burgess et al., (2020) recruited 46 BD participants and 42 control participants to wear an accelerometer to determine if the variance in cognitive task performance could be explained by PA, BMI, sleep and circadian rhythm, and found that only sleep explained a portion of the variance in the participants performance on an attention task. The study also reported that people with BD spent significantly less time per day in MVPA than controls (14mins) which was less time than the current study, and found no association between time spent in MVPA and depression symptoms (Hamilton Depression Rating Scale and Beck Depression Inventory) or (hypo)mania (Young Mania Rating Scale), unlike the current study, although did find a negative association between MVPA and BMI, as did the current study.

McGowan, Goodwin, Bilderbeck and Saunders, (2020) recently published an exploration of impulsivity, mood instability and Actigraph patterns in people with BD (N=31) and borderline personality disorder (BPD) and also used the MZ tool. Participants wore an Actigraph and used MZ as a daily mood monitoring tool. Data were collected over a three month period, and then MZ items were grouped into

‘positive’ ‘negative’ and ‘irritability’ factors. These were cross-sectionally explored to identify differences between BD and BPD on impulsivity and mood instability in relation to Actigraph patterns. The study found significant associations between BPD motor-activity, impulsivity and mood instability, however not for BD. It was noted however that the BD participants were considered ‘stable’ during the study period according to QIDS and ASRM scoring (also used to establish mood symptom severity in the current study). The current study however did find significant associations between individual MZ items (not grouped into ‘positive’ ‘negative’ and ‘irritability’) in a larger sample of BD participants, which included some participants whose ASRM and/or QIDS scores indicated the presence of high (hypo)mania and/or depression symptom severity. Given that people living with BD can remain stable for long periods of time with little to no mood impairment (APA, 2013), this may explain why McGowan et al., (2020) found no significant differences between their control group, and their BD participants who were considered stable at time of participation. This further highlights a need for future research to potentially consider a longitudinal monitoring of individual daily mood symptoms as well as PA and SB, alongside other relevant factors to capture these associations which may only be statistically significant during times of mood impairment or an increased severity or presence of particular symptoms.

In contrast to the results of study one of this PhD which showed anger to be something that might ‘fuel’ PA, anger was not found to have any statistically significant relationships with PA or SB in this study. However, anger is a feature of mood not experienced as frequently as perhaps ‘sadness’, and daily MZ anger scores showed little variation. A 7-day monitoring period may not have been long enough to establish any statistically significant relationships between PA, SB and

anger. Furthermore, despite the established links between anxiety and SB (Teychenne et al., 2015); anxiety and physical inactivity (McDowell, Dishman, Gordon, & Herring, 2019; Schuch et al., 2019); and the high comorbidity between BD and anxiety disorders (Ketter, 2015; Nabavi, Mitchell, & Nutt, 2015; Stratford et al., 2015; Suppes, Eberhard, Lemming, Young, & McIntyre, 2017) there were no statistically significant relationships of daily anxiety with PA or SB identified in this study.

Explorations between the self-reported sitting time of the MSQ and device-measured SB from the ActivPAL3 showed that for all weekday, weekend-day, average day and total week analyses, there were no significant differences between the two measures, and almost all data plots fell within the acceptable limits of agreement (Bland-Altman plots) which would indicate agreement between the two measures. Furthermore, the correlation analyses showed evidence of concurrent validity (r=0.283-0.344) which was in line with all the self-report validation studies detailed in Chapter two (Table 2.1, page 29) and greater than those reported for the Sedentary Behaviour Questionnaire (Rosenberg et al., 2010) and the Simple Physical Activity Questionnaire (Rosenbaum et al., 2020). Although the relationship between the MSQ and ActivPAL3 measures were only significant for weekend day and average day analyses, they bordered on significance for the weekday and total week analyses. However, the average day and total-week analyses highlight some proportional bias, with the MSQ reporting time spent sitting to be 47mins less per average day than the ActivPAL3, and a total of 6hrs less per week. Although 47mins a day may seem a small amount, this adds to a significant amount across the duration of a week, which may have an impact on population estimates of total SB time, and its relation to other outcomes (e.g., mood symptoms, health factors, etc.).

Therefore, although there is arguably a level of agreement between the MSQ and ActivPAL3 measures, and the identified differences were not considered significant, the MSQ should still be used with caution in this population as it likely provides an underestimation of SB at a group level. Some participants however overestimated rather than underestimated their SB, and so the MSQ did not provide a consistent underestimation of SB. In comparison to previous research exploring the validity of the MSQ in other populations, the MSQ did not perform poorly in this study exploring its validity in people with BD. Prince et al., (2020) found an average over or underestimtion per day of approximately an hour and a half in self-report tools, and Sasaki et al., (2019) reported an inital daily overestimation of 81mins from the MSQ validation in people with multiple sclerosis. Without further exploration into the completion of the MSQ in people with BD including validation of the individual sitting domains (e.g. using direct observation or logs alongside device-based measurements) it is not possible to be entirely confident of either an under or over estimation (and therefore consistent bias) of the MSQ to improve its use, as Sasaki et al., (2019) recently attempted to improve the use of the MSQ in people with multiple sclerosis.

Furthermore, there were stronger observed relationships between ActivPAL3 measured SB and self-reported mood than self-reported sitting time and mood which may be problematic for understanding relationships between SB and mood in this population, as there may be differences between perceived SB engagement with mood, and device-measured SB with mood. This warrants further exploration in a larger sample using the MSQ which may offer more variation of mood symptoms to identify relationships between self-report measures and mood, and to identify how time spent in different domains of sitting contributes to total time spent sitting, and

how the perception of these sitting behaviours relate to perceived mood symptoms, as the current study had a small sample size and poor mood variation to explore this.

5.6.1 Strengths

This study recruited 54 participants with BD to wear an ActivPAL3 activity monitor for a 7-day period, 51 of whom completed the study, exceeding the number of participants recruited for the IPAQ validation study (N=20) by Vancampfort, Wyckaert, et al., (2016). This is also the largest known sample to date of published research using the ActivPAL3 to explore PA and SB in this population. Furthermore, this study included relatively equal numbers of participants with BDI (N=27) and BDII (N=24) (although there were no significant differences of BD sub-type in PA or SB variables). Previous research had mostly included small sample sizes of participants with BD and/or mixed samples including various mental health diagnoses. Previous research had also included more participants with BDI and not directly compared the PA and SB levels between those with BDI and BDII as the current study has (see Appendix P).

Overall participants demonstrated excellent adherence to wearing the ActivPAL3 for the 7-day period and in completing the sleep and device removal log accurately, as visual inspections of the day-by-hour ActivPAL3 summary compared with the sleep log entries showed only small variations. Participants anecdotally reported the ActivPAL3 to be an easy to use and non-invasive activity monitor. Only one participant had to return the ActivPAL3 and withdraw from the study due to issues with applying the waterproof dressing correctly. Although a small number of other participants experienced initial issues with application, these were resolved via a telephone call with the researcher. To further strengthen participant adherence and to make application simpler, diagrams or a video demonstrating application of the

ActivPAL3 using the waterproof dressing would have been beneficial as the current study only provided participants with written instructions (Appendix K).

The daily use of the sleep and device removal log appeared to be a tool that helped maintain engagement and adherence during the study and encouraged participants to keep the monitor on as they had to record if and when they removed it. To further improve the accuracy of the sleep log to remove this from ActivPAL3 SB time, participants could also have been asked to report 'time woke up' and 'time got out of bed.' It was recognised during data collection that this information had not been collected on the sleep and device removal log as originally planned due to a formatting error on the document. However, participants still demonstrated accuracy with their reporting of sleep when compared with visual inspections of the day-by-hour summary report produced by the PAL technologies software, and to the automated algorithm used to remove time spent asleep from the time spent sedentary data.

The application of the automated algorithm to remove sleep and non-wear time was considered a strength of this study. Given the variations in sleep experienced by those with BD, and the high scores on the QIDS (depression) sleep disruption item, the use of this algorithm meant that sleep could occur at any point within a 24/h period, i.e. the algorithm did not rely on conventional population sleep times and did not exclude days due to too much or too little time spent asleep. A different algorithm not using the '10hr waking wear time' rule could have proven troublesome, as a minimum wear time is required to capture habitual PA and SB per day (Chapman et al., 2015a; McVeigh et al., 2016; Winkler et al., 2016). A lower minimum waking wear time can be problematic if reducing the waking wear time threshold results in more

data becoming ‘valid’ that is not representative of the 24/h period and so this is not advised (Winkler et al., 2016). For example, if 8hrs of waking wear time was to represent a whole 24/hr period, a participant could have removed the device, engaged with PA and forgot to put it back on, and then the device would only have the 8hrs of data and so their average time spent in SB across the week may indicate the person being more sedentary than they really are within a 24/h period. As the average device removal time was approximately only 5mins according to the sleep and device removal log, the above was not an issue affecting the data within this study due to excellent participant adherence and engagement. Furthermore, if a higher minimum waking wear time was used, participants with longer sleep durations may have had days excluded as an ‘invalid’ day, however their behaviour would still have been representative of their habitual PA/SB. Therefore, although the algorithm allows for changes to be made to the thresholds if considered necessary. For example, if the standard waking wear time rule excludes too many participants for analysis, making changes to this can result in inaccurate estimations of the PA and SB of those living with BD. Therefore, it was considered a strength of this study that in maintaining the standard ‘10hr waking wear rule’ this only excluded 7 participants from weekday SB analysis, and 9 participants from weekend-day SB analysis out of a sample of 51 participants, and this was due to failed recordings or battery failure on the ActivPAL3 rather than non-adherence.

The use of the MSQ in this study allowed the opportunity to identify that participants spent most of their time when sitting ‘watching television’ regardless of whether this was a weekday or weekend day, which is important information to consider when developing interventions aimed at reducing time spent sitting in people with BD. The least amount of time spent sitting was self-reported as ‘sitting at work’ for both

weekday and weekend days. Only 17/48 participants who responded to this MSQ item input a response greater than ’00:00’ which may account for why it was the least amount of time spent sitting, and why this domain demonstrated the greatest variability in scores, as it may be that only these 17 participants were employed or attended work during the study period.

This study was the first to explore the validity of the MSQ for use as a self-report SB tool in people living with BD, and has provided evidence of the levels of agreement of the MSQ against the ActivPAL3 activity monitor in a sample size just short of the recommended 50 for a validation study (Terwee et al., 2010).

5.6.2 Limitations

Although participants generally found the ActivPAL3 device simple and easy to use, only 44 participants had a full 7-days of data obtainable from the ActivPAL3. The other 7 participant recordings highlighted recordings that had failed, most often due to a battery failure which had ended the recording prematurely. During the study period four devices were replaced by PAL technologies under warranty following repeated issues with these devices. The longevity of devices and the battery life during recordings has previously been highlighted as an issue in research using activity monitors (Chapman et al., 2015b; Edwardson et al., 2015; Naslund et al., 2016a; Trost et al., 2005). These complications are something for researchers to consider and anticipate in terms of obtaining the required sample size, maximising the number of valid days obtainable from the device, as well as managing delays due to sending out replacement devices to participants and troubleshooting issues with the device.

MVPA is calculated from the ActivPAL3 ‘stepping time’ and cadence, and the STATA code used in this study did not distinguish between vigorous and moderate PA or provide information on bouts of MVPA, just the total time, and so it is possible that in the current study the time spent in MVPA is particularly high as it includes all detections of moderately paced walking (rather than bouts of 10mins), and is not accompanied by other measures such as heart rate or global positioning systems to determine intensity of the movement.

Multiple testing is a limitation to consider in regards to the correlation analyses which explored relationships between PA, SB and mood as no adjustments were made to the accepted value identifying a significant result. Adjusting the accepted p-value by the number of correlations made would have greatly restricted the analysis given the sample size (N=51) and increased the risk of a type II error occurring. It is acknowledged, however, that by not adjusting the accepted significance value, there was an increased risk of a type I error occurring. As each set of correlations are exploring relationships between similar constructs/sub-scales of the same construct, it was expected that there would be similar outcomes and multicollinearity.

Furthermore, the daily correlations using MZ mood symptoms included up to 357 ‘days’ of data, and so each participant is represented up to 7 times in each daily analysis and so these are not independent observations. This may have contributed to why there were more significant correlations observed in the daily analyses than the weekly analyses which only included one measure from each participant.

All of the device-measured PA and SB variables used in this study originated from either the ActivPAL3 pre-defined ‘sedentary’ ‘standing’ or ‘stepping’ categories which caused issues of singularity as multiple variables were measuring aspects of the

same construct. For example, ‘time spent in MVPA’ and ‘time spent in light PA’ are both subcategories of ‘time spent stepping,’ and variables relating to time spent in various SB bouts are subcategories of total ‘time spent in SB’. PA and SB variables were also highly correlated in this study, which caused the issue of multi-collinearity. Due to the above issues, as well as the low variation in mood scores, it was not feasible to explore the variance and potential contribution of PA or SB variables in mood scores using regression models.

Further, it was also therefore not feasible to complete a time-series analysis (cross-lag model) within this study, due to the low variance in mood, small sample size, and short study period which only offers 7 time points for exploration (recommended time points=50, minimum=20: Jebb, Tay, Wang, & Huang (2015); McCleary, Hay, Meidinger & McDowall (1980)). Furthermore, participants did not complete the study at the same time due to the number of ActivPAL3s available, and so seasonality was an issue when considering time-series analysis, as some participants completed the study during the Summer, and some in the Winter. This type of analysis if conducted in a larger sample across a longer time-period (and at the same time) may have helped identify whether a change in mood precedes a change in PA and/or SB, or whether a change to either PA and/or SB precedes a change in mood.

The current study made use of available BDRN data (see Chapter three, page 91) alongside other data collected for this study (such as BMI and medication use) to explore potential factors which may confound the relationship between PA, SB and mood in people living with BD. However, these analyses were carried out using relatively small sample sizes to make comparisons. Therefore, it is possible that some variables which did not show a significant difference between groups (e.g. BD

sub-type) and those which did not show associations with PA, SB and mood (e.g. age) may have been identified in a larger sample. Information on medication compliance during the study period was not collected, which is a limitation to the analysis which identified a difference between time spent in SB and (hypo)mania on the use of anti-depressants, and the effect of various combinations of medications were not explored. Not all participants had previously responded to BDRN's medical history questionnaire with their physical health co-morbidities and not all participants provided their medication use as part of the current study. A further limitation is that BMI was self-reported from participants, and only 44 participants provided this information.

Although the inclusion of the MSQ to explore its validity as a self-report SB tool for use in BD is considered a strength of this study, not all participants completed all questions on the MSQ and so not all 51 participants were included in the analysis: 3 participants were excluded completely, and around 20% of participants did not have full MSQ data and so were only included in parts of the analysis. For weekday analyses, only 44 participants were included, and for weekend-day analyses, 42 were included, and for the average day and total week analyses, only 37 were included. Therefore this study's attempt at validating the MSQ for use in BD fell short of the recommended sample size of 50 for validation studies (Terwee et al., 2010). Invalid data appeared to be mostly due to misreading the 'on average per day' as a weekly total. Blanks may have meant to have been '00:00' or perhaps assumed it would be copied over from weekday time spent sitting. Missing/invalid data is a limitation of the MSQ, and something to be aware of when planning to use it in future. Larger samples may be needed to account for the number of responses

excluded based on missing/invalid data, due to their being no agreed way of handling this data in the original publication (Marshall et al., 2010).

Although it would have been beneficial to include other SB, and PA self-report questionnaires (such as the IPAQ) to explore their validity and determine which was the most suitable PA and SB tool for use in BD, this was not done to reduce participant burden and to avoid participants using a response to one questionnaire to inform their response to another. Furthermore, another possible limitation of this study is that participants received the study pack which included the 7-day recall questionnaires at the start of the study, and they may have looked at these ahead of the day of completion which may have impacted on their behaviours and recall during the week if they knew they would have to answer a questionnaire on these. No spot-checks were carried out over the 7-day period, and so whilst participants were asked to complete MZ and the sleep and device removal log daily, and the 7-day recall questionnaires on day 7, it is possible participants may have completed these at different times.

Furthermore, 11 participants from study one who were interviewed about their experiences of PA, SB and mood also participated in this study. It is therefore possible that although there was a minimum period of two months between any study one participants being recruited for study two, these participants may have had a heightened awareness of their behaviours and therefore behaved or responded differently as a result. However, it could also be argued that all participants who volunteered to take part in this study may have done so because they believe there to be a relationship between PA and/or SB and mood and so were personally interested in the research and behaving in a way that would support this belief.

5.6.3 Conclusions

This study has identified that there are relationships between PA, SB and mood symptoms using a device-based measurement of PA and SB in people living with BD. There were a greater number of associations between PA and mood than SB and mood, with daily PA being negatively associated with depression and positively with (hypo)mania symptoms. Positive associations were identified between SB and both depressive symptoms, and (hypo)manic symptom severity. There were also a greater number of associations overall between daily PA, SB and mood symptoms than weekly PA, SB and mood symptom severity. Furthermore, BMI, gender and the length of BD illness (yrs) were associated with PA and mood and confounded the relationship between PA and mood symptoms associated with (hypo)mania (elation and feeling energetic). The use of anti-depressants was found to be associated with both SB and mood, and confounded the relationship between SB and (hypo)mania.

This study also explored the validity of the MSQ in people living with BD. Given the absence of another self-report tool with any known validity to calculate SB in this population, the MSQ can be used in people with BD as it provides acceptable levels of agreement to a device-based measurement, however future research using the MSQ in this population should highlight that the MSQ may underestimate the amount of time spent sitting at a group level by around 47mins and consider how that may impact their results and any conclusions/recommendations made following its use.

6 Chapter Six: Relationships between subjectively measured physical activity, sedentary behaviour, & bipolar disorder mood symptoms

6.1 Introduction

This chapter continues the exploration of the relationships between physical activity (PA), sedentary behaviour (SB) and mood symptoms in people with bipolar disorder (BD) by outlining the third and final study of this PhD. This study explored subjective relationships between self-reported 7-day recall accounts of PA, SB, and mood in people with BD using a cross-sectional design. This study provides a representation of the UK BD population's PA and SB in relation to mood symptom severity and associated factors in a large sample of participants living with BD.

Study two (chapter five) identified several significant relationships between device-measured PA and SB using an ActivPAL3 activity monitor with self-reported depressive and (hypo)manic mood symptoms. In study two only the device-based measure of SB (ActivPAL3) showed a positive relationship with (hypo)mania in a sample of 44 participants. However, it is unclear whether relationships between self-reported PA, SB and mood would be found in a larger sample of BD participants where there is likely to also be greater variability in mood symptoms to explore these relationships, which was a limitation of the analyses in study two. Study two also concluded that in the absence of another self-report tool offering stronger validity in people living with BD, that the Marshall Sitting Questionnaire (Marshall et al., 2010) (MSQ) is a suitable self-report tool for calculating SB in BD after providing acceptable agreement against an ActivPAL3 (see Chapter five). Furthermore, study two identified and discussed the limitations of the MSQ in this population, and so these can now be considered when interpreting the results in this current study.

Previous research has already shown support for the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) as a suitable tool for estimating PA levels in those living with a severe mental illness (SMI) (Faulkner et al., 2006), and some support for those specifically living with BD (Vancampfort et al., 2016e). Furthermore, there are also several published works which have investigated PA levels in mental health populations using the IPAQ (Branco et al., 2014; Fellendorf et al., 2017; Masa-Font et al., 2015; Stubbs et al., 2018a; Vancampfort et al., 2015b) which offer comparability with the results of this study which uses a larger, population based sample (i.e. not inpatients).

The IPAQ includes a singular question used to estimate total time spent sitting across a 7-day period, and so provides no domain related data, unlike the MSQ which was another reason for including the MSQ in this study. It was important to this current study that SB domains were reported to identify any significant relationship between the type of SB engaged with, and BD mood symptoms. It was identified in the study one interviews (see Chapter four) that the type of sitting behaviour engaged with may play an important role in the regulation of (hypo)manic mood symptoms, and so it was important to explore the relationships between time spent in SB domains and mood in this study now that the overall validity of the MSQ had been explored in study two (Chapter five). Understanding the strength of any relationships between SB domains and mood symptoms could be valuable information for future research aiming to develop behavioural interventions targeting a reduction in SB in people with BD.

Previous cross-sectional research on PA and SB which has included people living with BD has been largely underrepresented and the sample sizes of those with BD have been relatively small (Farholm, Sørensen, & Halvari, 2017; Fellendorf et al.,

2017; Subramaniapillai, Arbour-Nicitopoulos, et al., 2016a; Vancampfort et al., 2016b). Furthermore, relationships between PA, SB and the mood symptoms associated with BD (such as BD depression and (hypo)manic symptoms) remain unclear. The main purpose of this study was therefore to explore subjective relationships between PA, SB and mood symptom severity in a large sample of people living with BD.

6.2 Aims & Objectives

Aim: To explore the relationships between self-reported PA, SB and depressive and (hypo)manic mood symptoms in a large sample of people living with BD.

Objective 1: To gather self-reported 7-day recall PA (International Physical Activity Questionnaire: IPAQ) and SB (Marshall Sitting Questionnaire: MSQ) data, and report on the PA and SB of people living with BD.

Objective 2: To gather self-reported 7-day recall depressive (Beck Depression Inventory: BDI-21) and (hypo)manic (Altman Self Rating Mania Scale: ASRM) mood symptoms in people living with BD.

Objective 3: To explore the relationships between subjectively measured self-reported 7-day recall PA (IPAQ), SB (MSQ) and depressive (BDI-21) and (hypo)manic (ASRM) mood symptoms.

Objective 4: To explore relationships between subjectively measured self-reported 7-day recall time spent in sitting domains and depressive (Beck Depression Inventory) and (hypo)mania symptoms (Altman Self Rating Mania Scale)

Objective 5: To identify potential confounding factors in the relationships between self-reported PA (IPAQ), SB (MSQ) and depressive (BDI-21) and (hypo)manic (ASRM) mood symptoms.

6.3 Method

6.3.1 Participants

6.3.1.1 Recruitment process

Chapter three previously outlined the BDRN recruitment process and the general method of recruitment used for this PhD.

All BDRN participants who had consented to being contacted again following their initial BDRN interview receive a bi-annual mailshot. This mailshot is a compilation of short questionnaires that BDRN use to explore various psychological, biological and social variables in people with mood disorders. The mailshot is also a valuable opportunity for BDRN participants to update their personal details and provide any feedback/suggestions to the research team for the following year. One of the suggestions from 2017 was to explore PA in relation to mood disorders.

In 2017, BDRN received approximately 2100 (28%) responses to their biannual mailshot, of which approximately 1300 (61.9%) of participants had a diagnosis of either BDI or BDII, and so it was expected that a similar number of responses would be returned for the 2019 mailshot which included questionnaires on PA, SB and mood for this study. For the 2019 mailshot, BDRN included recommendations from a Cochrane review (Edwards et al., 2009) for maximising response rates to questionnaires, such as providing an online option, and marking the postal envelope as confidential.

Prior to any participant recruitment, the online and paper versions of the mailshot were piloted within the BDRN team to ensure usability of the mailshot.

To try to maximise response rates, all participants received a reminder email or letter two weeks after the initial invitation went out. Total recruitment figures are outlined below in Figure 6.1:

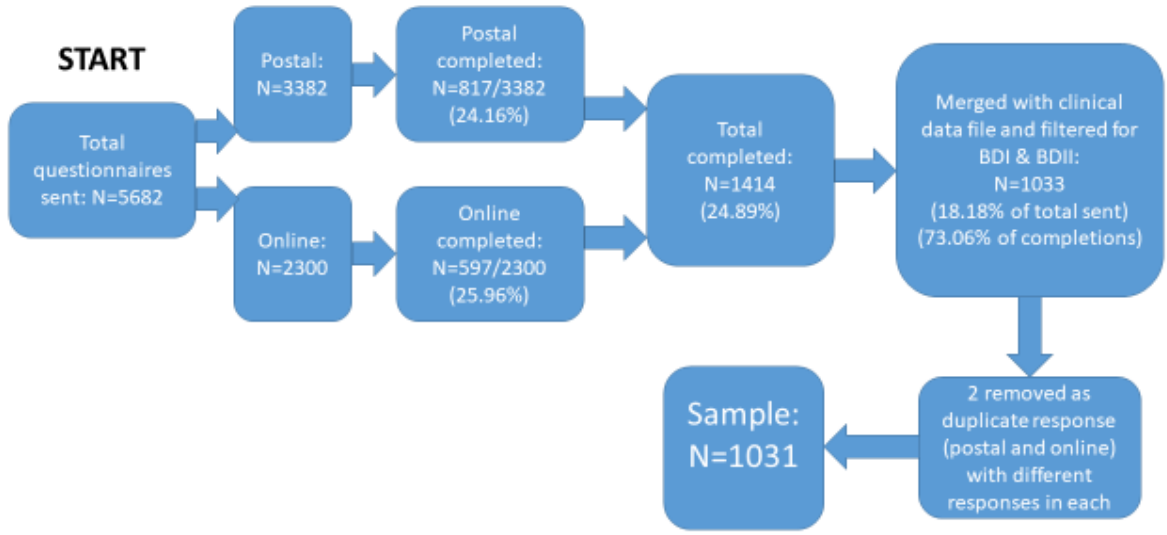


Figure 6.1 Study three recruitment flow chart

Figure 6.1 shows that 25% of BDRN participants contacted about this study returned the questionnaire mailshot. 597 (26%) completed an online version in Bristol Online Survey (now known as Online Surveys; onlinesurveys.ac.uk), 817 (24%) completed and returned a postal version. Figure 6.1 shows that the method of administration (postal or online) made little difference to the response rate, as fewer than 1% of responses were provided online compared to postal.

6.3.2 Measures

6.3.2.1 The International Physical Activity Questionnaire

The International Physical Activity Questionnaire (IPAQ) (Short Version: 7 items) (Craig et al., 2003) (Appendix A) was used to gather self-reported time spent (hours/minutes on average per day) in PA (vigorous intensity, moderate intensity, and walking) using the last 7-day format.

6.3.2.2 The Marshall Sitting Questionnaire

The Marshall Sitting Questionnaire (MSQ) (5-item) (Marshall et al., 2010) (Appendix B) was used to gather self-reported total and domain specific sitting time (hours/minutes) for the average weekday and weekend day, over the last 7-days.

6.3.2.3 Depression & (hypo)mania questionnaires

BDRN already include two standard mood questionnaires in their mailshot, which were used in this study: The Beck Depression Inventory (BDI-21) (Beck, Ward & Mendelson, 1961) (Appendix E) to measure depression and the Altman Self-Rating Mania Scale (ASRM) (Altman et al., 1997) (Appendix C) to measure (hypo)mania (also used in study two). These are well established, and two of the most commonly used (Scott & Murray, 2018) 7-day recall questionnaires for assessing BD mood symptoms. BDRN participants who have previously engaged with the on-going research BDRN carry out are familiar with the regular use of these questionnaires (see Chapter three) which was an additional, practical reason for selection.

6.3.3 Procedure

Data collection occurred between March 2019 and August 2019. The BDRN mailshot was prepared by the whole BDRN research team and included the BDI-21, ASRM, IPAQ and MSQ. BDRN participants with a valid email address received an electronic version of the questionnaire compilation online via email link, with the option to request a postal paper mailshot with a free-post returns envelope to the University of Worcester. Those without a valid email address on record received the postal paper mailshot with an option to request an online mailshot if they provided BDRN with their email address. As the returned postal questionnaires arrived they were scanned using Formic software which is designed to scan and store data from questionnaires. The scanned questionnaires were manually checked and any scanning errors were corrected. The scanning and checking of the paper questionnaires was an on-going process during data collection and took approximately three months to complete. In September 2019, the online questionnaire responses were downloaded into excel, and merged with the scanned paper questionnaire excel file downloaded from the Formic software.

The excel spreadsheet of the combined online and paper responses were then merged with data from BDRN's clinical database (see Chapter thee, page 91) which included gender, ethnic origin, age (yrs), age of onset of BD illness (yrs), length of BD illness (yrs), number of depressive episodes per illness year, number of (hypo)manic episodes per illness year, and physical health comorbidities. This was then filtered to identify participants with a best estimate main lifetime diagnosis of BDI or BDII (N=1031). Of these, 533 (52%) participants had completed a paper questionnaire, and 498 (48%) had completed an online questionnaire.

6.4 Data handling, cleaning & assumptions

This section outlines the steps taken to prepare, check, and process the various data collected, and why the approaches taken for data preparation were required. This section also reports on analysis preparations (such as checking if parametric assumptions were met) and inclusion and exclusion criteria for analysis.

The International Physical Activity Questionnaire

The IPAQ data were processed and data cleaned following published guidelines for data processing and analysis of the IPAQ (short-form) (2005) which includes rules for a minimum amount of PA (10mins) and maximum PA (16hrs). It is recommended participants with missing data are excluded from analysis. The only data cleaning suggestion not followed in this study was the recommendation that daily total PA time is truncated (recoded) at 3hrs (180mins) per activity (vigorous/moderate/walking) to normalise data which is reportedly skewed in large population samples so that the maximum amount of time per week for each activity is 21hrs (3hrs*7day). This rule was not followed as a maximum value had already been applied to the data (see above:16hrs) and due to concerns that recoding the data would affect the assessment of the relationship between PA and mood symptoms. Furthermore, the purpose of this study was to first and foremost report on the relationship between subjectively measured PA, SB and BD mood symptoms, and so it was important to consider whether high self-reported (hypo)manic symptoms were associated with high self-reported PA levels on the IPAQ.

Following the IPAQ data processing and cleaning rules, 30 participants were excluded due to not completing the IPAQ at all, 169 participants were excluded due

to missing data, and 8 participants due to extreme values (over 16hrs per day in PA). A total of 824 (79.92%) participants were included in analyses involving the IPAQ. Hours was chosen as the unit of measurement instead of minutes to make the data more meaningful when presented against total week sitting time (MSQ).

All of the processed IPAQ variables were explored to assess whether these showed a normal data distribution, and whether parametric assumptions were met using the explore function in IBM-SPSS-24 (ibm.com). The IPAQ data were considered not normally distributed: the p-values on the normality tests were less than 0.05, (Kolmogorov-Smirnov and Shapiro-Wilk) and the standard deviations were often greater than the means. The histograms did not show a definite bell curve for all variables, and points fell off the lines of the normality plots. Due to the non-normal distribution of scores, and the recommendation in the IPAQ scoring protocol, the IPAQ data in this study were analysed using non-parametric testing, and median values and interquartile ranges reported.

The Marshall Sitting Questionnaire

Average weekday sitting time was calculated for each participant by first converting each of the five MSQ items from hours and minutes into hours only using an excel formula. The sum of the five-items then provided the total time spent sitting (hrs) on an average weekday for the 7-day study period. This process was repeated for the five weekend-day MSQ items to provide total time spent sitting (hrs) on an average weekend-day for the 7-day period. Hours was chosen as the unit of measurement instead of minutes to make the data more meaningful when presented as totals for the week.

Total self-reported sitting time for the week was calculated in excel: (weekday total sitting time_hrs x5) + (weekend day total sitting time_hrs x2).

All of the MSQ variables (individual items and total scores) were explored to assess whether these showed a normal data distribution, and whether parametric assumptions were met using the explore function in IBM-SPSS-24 (ibm.com). The MSQ data were considered not normally distributed: the p-values on the normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) were less than 0.05, and the standard deviations were often greater than the means. The histograms did not show a definite bell curve for all variables, and points fell off the lines of the normality plots.

Following the preliminary analysis to check normality of the MSQ, some of the self-reported MSQ items showed estimates of domain and total sitting time that required some consideration before including or excluding certain participants from all or part of the analyses that included the use of the MSQ. The same data processing techniques applied for the MSQ in study two (Chapter five) were applied to this study. This meant that participant responses totalling over 17hrs a day sitting time were excluded completely from analysis, and participants with missing or invalid data were also excluded.

The above exclusions meant for weekday analysis, 245 participants were excluded due to missing data, 14 due to invalid data (over 24hrs), and 43 due to outliers (over 17hrs). For weekend-day analysis, 333 participants were excluded due to missing data, 11 due to invalid data (over 24hrs), and 32 due to outliers (over 17hrs). Some responses fell in to more than one category for exclusion. A total of 623 (60%) participants had full MSQ data and were included for the total week and average day

analyses. 729 (71%) were included in weekday analysis, and 655 (64%) were included in weekend-day analysis.

Following the above exclusions, all MSQ individual items and totals were re-explored to re-check distribution and parametric assumptions. Following this, there was no change to the distribution, and so non-parametric testing was used in analysis and medians and interquartile range was used to report domain related sitting time.

The Beck Depression Inventory

The sum of the 21 items in the BDI-21 provided a total score, with a maximum score of 63. Scores were totalled in excel.

Question 19 of the BDI-21 has two parts. The first asks about weight loss ('I haven't lost much weight' /I have lost more than 5 pounds/ 10 pounds/ 15 pounds). The second part asks 'I am purposely trying to lose weight by eating less' with a response of 'yes' or 'no' available. If participants responded 'yes,' the score of the first part of the question was recoded to '0' to ensure this was not misclassified as a symptom of depression. A total of 471 participants said that they were purposely trying to lose weight. Of these, 130 reported a degree of weight loss, and so their score was recoded as '0.'

During data collection, it was identified by the BDRN research team that items 16 *'I can sleep as well as usual'* and 17 *'I don't get more tired than usual'* of the BDI-21 were missing from the paper versions of the questionnaire. Consideration was then taken for these two missing items on how this may impact data analysis and in particular, the total BDI-21 score. There was a significant difference between the paper (BDI-19) and online (BDI-21) total score (U=119645.00, N1=498 N2=533, p=0.006), however the difference between the mean of the total scores was less

than one point (0.93). Once items 16 and 17 were also removed from the online questionnaires, there were no significant differences (U=131230.500, N1=498 N2=533, p=0.755). This indicated that although items 16 and 17 significantly contributed to and increased the total BDI-21 score (herein referred to as 'BDI-19') by approximately one point, the scores between the online and paper questionnaires were similarly distributed, and so removing items 16 and 17 from the online scores would not affect the distribution of the scores for analysis using correlations. This also allowed analysis to continue using one sample rather than decreasing the statistical power by splitting all analysis by 'paper' and 'online' questionnaire responses.

BDRN data cleaning rules were then applied to the BDI-19 to handle missing data, which allow for 10% of the items to be missing for the total score to still be included in analysis. Of the 19 items included in the BDI-19 following the omission of items 16 and 17, this meant 1.9 items (rounded to 2 items) were allowed to be missing for the total score to be included in analysis. This meant that 24 participants were excluded from analysis including the BDI-19 due to missing data. A total of 1007 participants were therefore included in analysis.

All BDI-19 items and the total score were checked using the explore function of IBM-SPSS-24 (ibm.com) to ensure all responses fell within the altered possible ranges following the removal of items 16 and 17 form the total score (BDI-19: items=0-3, total=0-57).

Altman Self-Rating Mania Scale

The sum of the 5-items of the ASRM provided a total score. The maximum score possible is 20. Scores were totalled in excel. All ASRM items and total scores were required for analysis, and were checked using the explore function of IBM-SPSS-24 (ibm.com) to ensure all responses fell within the possible ranges (ASRM: items=0-4, total=0-20).

Due to missing data from the ASRM in this study, and in line with BDRN's data cleaning processes, if more than one item was missing from the ASRM this participant was removed from analysis using the ASRM total score. 1001 participants had completed the ASRM in full and 13 participants had completed 4 out of 5 individual ASRM items. 1014 participants were therefore included in analysis concerning the total ASRM score, and 17 were excluded due to missing data (14 did not complete the ASRM at all, and 3 participants only completed 3 of the items).

All ASRM items and the total score were checked using the explore function of IBM-SPSS-24 (ibm.com) to ensure all responses fell within the possible ranges (ASRM: items=0-4, total=0-20).

Mood state

Although the total scores of the BDI-19 and ASRM provide a more statistically sensitive approach to analysis, the questionnaires were initially designed to screen for an episode of depression (BDI-19) and (hypo)mania (ASRM) and its severity using cut off values from the total score. For participants who had a total score for both the BDI-19 and the ASRM following the previous data processing and cleaning steps (N=990, 96.02%), the total scores were used to categorise mood state to

identify how many people, if any, met the criteria for a mood episode when they completed the questionnaires according to the cut off values. These cut off values were not adjusted following the identification of the two missing BDI-19 items as the difference in score was only one point.

On the BDI-19 a score of 0-9 indicates a 'normal' range of depressive symptoms, 10-18 indicates mild to moderate depression, 19-29 indicates moderate to severe depression, and 30+ indicate severe symptoms of depression (Beck, 1961). On the ASRM, a score of 5 or higher indicates a (hypo)manic mood state (Altman et al., 1997).

A variable was created to describe the mood state of the participant sample for the 7-day period as either euthymic, depressed *('mild to moderate'/'moderate to severe'/'severe'),* (hypo)manic, or in a mixed state (experiencing (hypo)mania and depression).

As a score of 9 or less on the BDI-19 and a score of 4 or less on the ASRM indicated no significant mood symptoms, these participants were coded as *'euthymic'*. As a score of 9 or less on the BDI-19, but 5 or more on the ASRM indicated (hypo)mania, these participants were coded as *'(hypo)manic'*. As a score of 10 or more on the BDI-19 but 4 or less on the ASRM indicated depression, but no (hypo)mania, these participants were coded in relation to the level of depression indicated by their BDI-19 score *('mild to moderate'/'moderate to severe'/'severe')*. As a score of 10 or more on the BDI-19 indicated a level of depression, and a score of 5 or more on the ASRM also indicated (hypo)mania, these participants were coded as *'mixed state.'*

Only the total BDI-19 and ASRM scores were used in any statistical analysis, (i.e. not the categorical approach). The purpose of determining mood state and assigning

participants to mood categories was to describe the mood state of the participant sample only.

Sociodemographic BDRN data

BDRN provided access to sociodemographic data previously collected from their participants. The data used in this study included gender, age (yrs), ethnic origin, self-reported physical health co-morbidities and lifetime psychiatric history: age of BD illness onset (yrs); length of BD illness (yrs); and average number of depressive and (hypo)manic episodes (per illness year). These data were collected by BDRN during initial recruitment, in the processes described in Chapter three (page 91) and was included in the current study to describe the participant sample and explore potential confounding factors in the relationship between PA, SB and mood.

6.5 Data analysis plan

Analysis was planned and structured in line with the study aim and objectives. Figure 6.2 below outlines the analysis plan to meet the objectives of this study. Analysis was carried out in IBM-SPSS-26 (ibm.com)

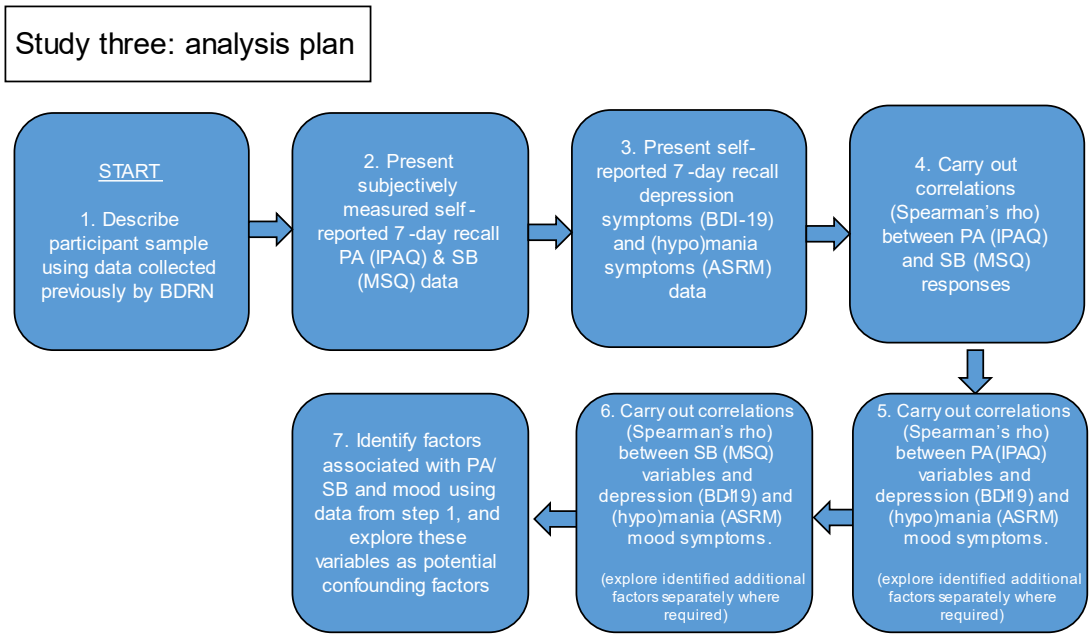


Figure 6.2 Study three analysis plan

As the correlations to explore relationships between PA, SB and mood included ratings data (mood) and the PA (IPAQ) and SB (MSQ) variables were not normally distributed and did not meet parametric assumptions, Spearman's rho correlation tests were used for steps 4-7.

At step 7, variables from step 1 were explored to identify potential confounders in the relationships identified between PA, SB and mood (steps 5 & 6) i.e. factors which were associated with both PA/SB and mood. Nominal variables: *gender (males/females), diagnosis (BDI/BDII), and physical health co-morbidities (yes/no for each condition)* were explored using Mann-Whitney U-tests to identify statistically

significant differences between groups in PA or SB engagement, and mood. Continuous variables *(age, number of (hypo)manic episodes per illness year, number of depressive episodes per illness year, length of BD illness[yrs], and age of BD illness onset [yrs])* were explored using Spearman's rho correlation tests. Where factors were found to be associated with both PA/SB and mood, any significant analyses from steps 5 and 6 were explored further in relation to these factors (e.g. split analysis by groups).

For all of the above analyses, the significance level was set at $p<0.050$. The effect sizes of correlations are reported in line with Cohen (1988): small (r=0.10-0.29) medium (r=0.30-0.49) and large (r=0.50-1.0).

6.6 Results

6.6.1 Participant descriptive information

Gender

Of the 1031 participants, 703 (68.19%) were female, and 328 (31.81%) were male.

Ethnic origin

901 participants (87%) identified their ethnic origin as ‘UK white,’ 42 participants (4%) as West European, 8 participants (0.8%) identified as Asian, 6 participants (0.6%) as African/ Caribbean, and 48 participants (5%) identified as mixed/ multiple ethnic group. 26 participants (3%) selected ‘unknown.’

Age

The youngest participant in the study was 23 years old, and the oldest was 83 (range=60.00). The mean age was 56.78 (±11.66).

Lifetime psychiatric history

704 participants (68%) had a best estimate main lifetime DSM-IV diagnosis of BD type I (BDI), and 327 (32%) had a diagnosis of BD type II (BDII). Table 6.1 below provides lifetime psychiatric summary figures of participants’ BD clinical history.

Table 6.1 Lifetime psychiatric history

Lifetime psychiatric history	Min	Max	Range	Mean (±SD)
Age of illness onset* (yrs)	5	68	63	23.41 (9.69)
Length of illness (yrs)	3	71	68	33.37 (12.57)
Average number of (hypo)mania episodes per illness year	0.02	25.00	24.98	0.59 (1.36)
Average number of depressive episodes per illness year	0.00	26.67	26.67	0.74 (1.49)

** onset of symptoms occurring within the context of a mood episode that produce clinically significant impairment (BDRN)*

Physical health co-morbidities

The most frequently reported physical health conditions for participants in this study included: elevated cholesterol (N=268/948, 28%); migraine (N=248/950, 26%); hypertension (N=221, 23%); asthma (N=213/948, 22%); and thyroid disease (hypothyroid N=129/948, 14%; hyperthyroid N=17/948, 2%; unspecified N=52/948, 5%).

6.6.2 Subjectively measured physical activity & sedentary behaviour

Objective 1: *To gather self-reported 7-day recall PA (IPAQ) and SB (MSQ) data, and report on the PA and SB of people living with BD.*

6.6.2.1 Physical activity

Table 6.2 below shows the descriptive statistics of the self-reported 7-day recall IPAQ variables (N=824).

Table 6.2 Descriptive statistics of the self-reported 7-day recall IPAQ variables (N=824)

IPAQ PA Variables: (N=824)	**Min**	**Max**	**Range**	**Median (IQR)**
Total time spent in vigorous intensity PA over 7-day period (hrs)	0.00	52.50	52.50	0.00 (0.00, 2.00)
Total time spent in moderate intensity PA over 7-day period (hrs)	0.00	73.50	73.50	0.00 (0.00, 2.00)
Total time spent in MVPA over 7-day period (hrs)	0.00	84.00	84.00	1.00 (0.00, 5.00)
Total time spent in walking over 7-day period (hrs)	0.00	87.50	87.50	3.50 (1.17, 7.00)
Total time spent in PA (all) over 7-day period (hrs)	0.00	104.00	104.00	6.09 (2.50, 14.00)
Total METs over 7-day period	0.00	34209.00	34209.00	1485.00 (528.00, 3465.75)
Average time spent in PA per day during 7-day period (hrs)	0.00	14.86	14.86	0.87 (0.36, 2.00)

Table 6.2 shows that, on average, participants self-reported spending 3hrs 30mins a week walking, and an hour in MVPA. Table 6.2 also shows that on the average day during the 7-day period, participants engaged in a form of PA (walking, or MVPA) for 52.2mins a day. Figure 6.3, 6.4 and 6.5 below show a visual description of the distribution of data for the original three variables collected in the IPAQ: time spent in vigorous intensity PA, moderate intensity PA, and walking. Histograms are presented instead of box plots as the medians for vigorous and moderate intensity PA were '0.'

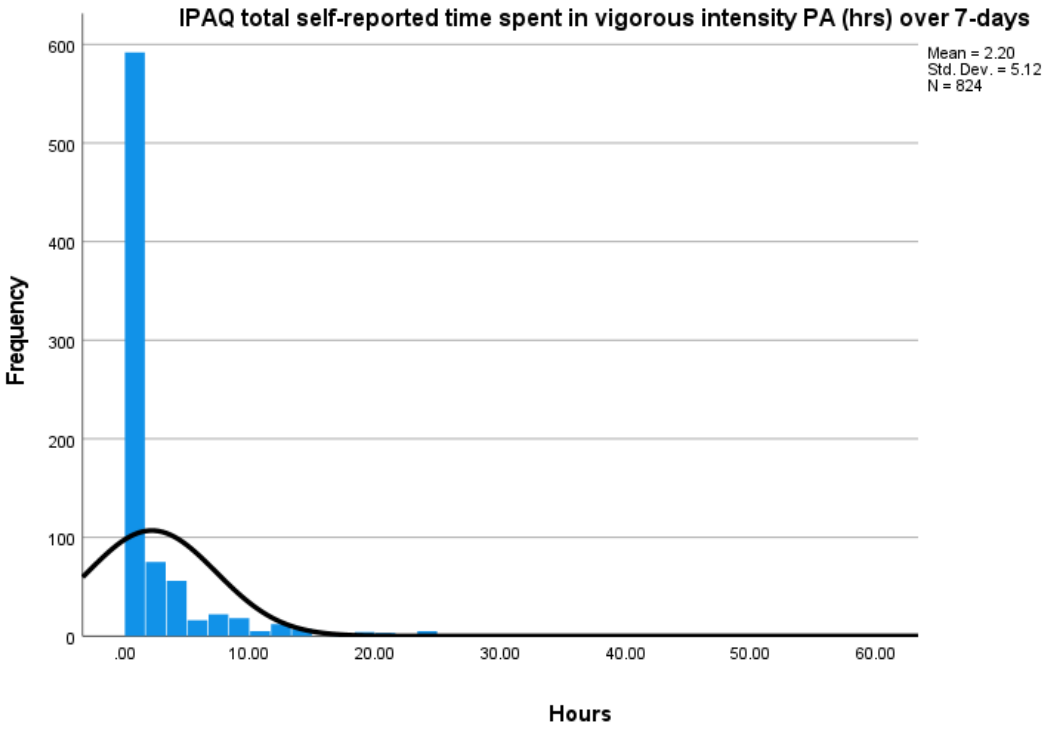


Figure 6.3 Total self-reported time spent in vigorous intensity PA (IPAQ) (N=824)

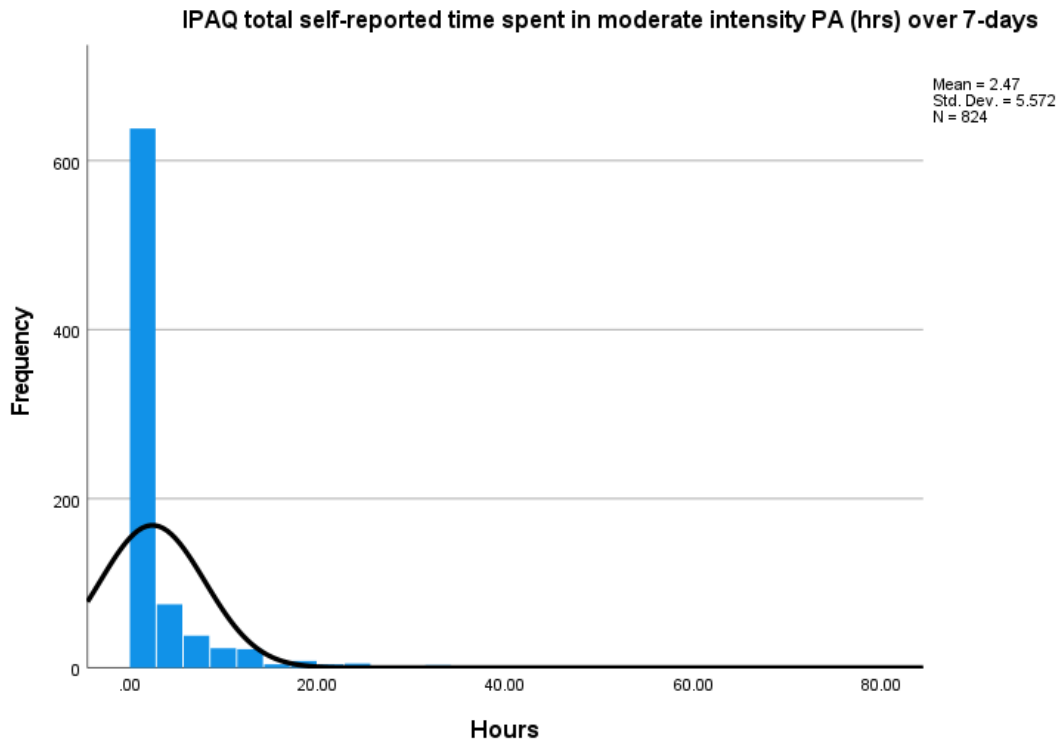


Figure 6.4 Total self-reported time spent in moderate intensity PA (IPAQ) (N=824)

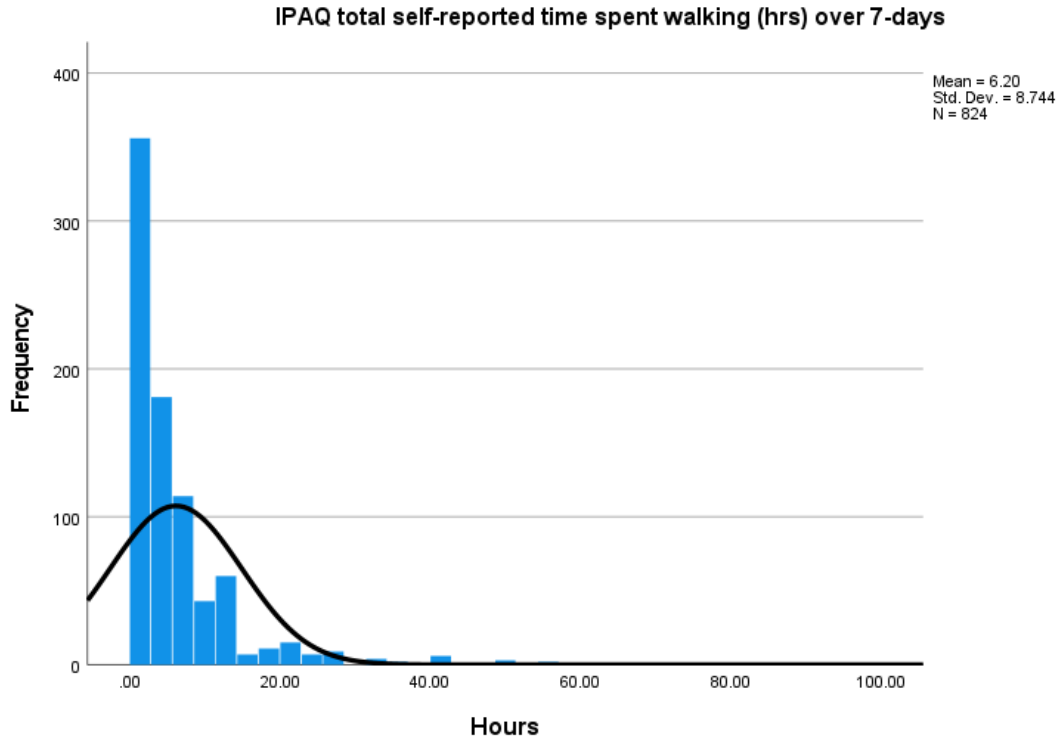


Figure 6.5 Total self-reported time spent walking (IPAQ) (N=824)

Figure 6.6 shows participant PA level classification, according to the categories and criteria outlined below by the IPAQ (short-form) (IPAQ, 2005):

High PA level

a) vigorous-intensity activity on at least 3 days achieving a minimum total physical activity of at least 1500 MET-minutes/week

OR

b) 7 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum total physical activity of at least 3000 MET-minutes/week.

Medium PA level

a) 3 or more days of vigorous-intensity activity of at least 20 minutes per day

OR

b) 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day

OR

c) 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET-minutes/week.

Low PA level

All participants who do not meet the criteria for 'medium' or 'high' PA categories.

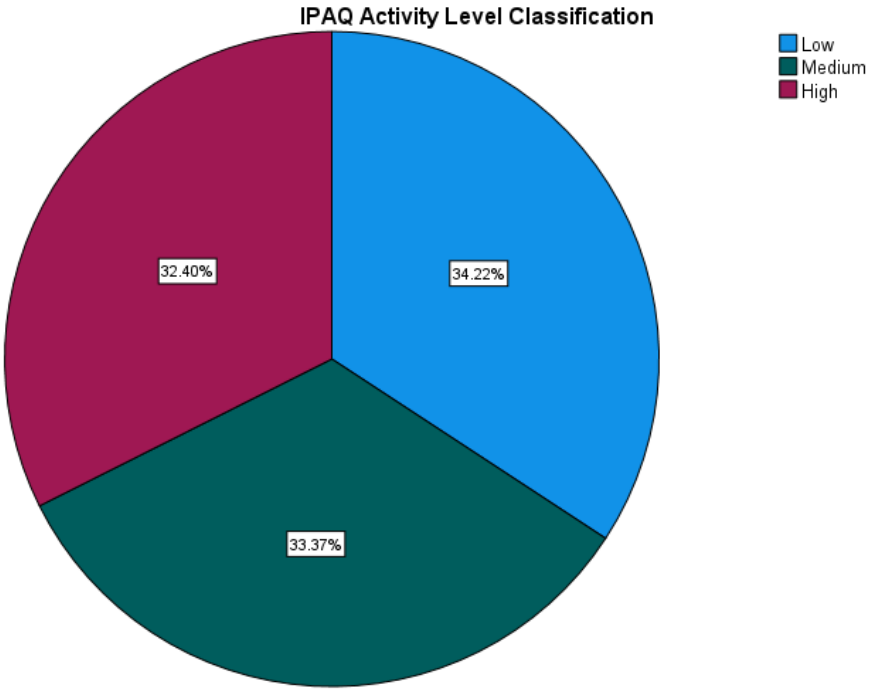


Figure 6.6 Activity level classification according to defined IPAQ categories (N=824)

Figure 6.6 above shows that most participants fell into the 'low' category of PA engagement followed by 'medium' and then 'high,' although the difference between the three groups is small, with each group accounting for approximately a third of all participants.

As the IPAQ classification of PA levels differ from the CMO (2015, 2019) guidelines of 75mins vigorous to 15mins moderate intensity PA week, Figure 6.7 below outlines the percentage of participants who met these guidelines.

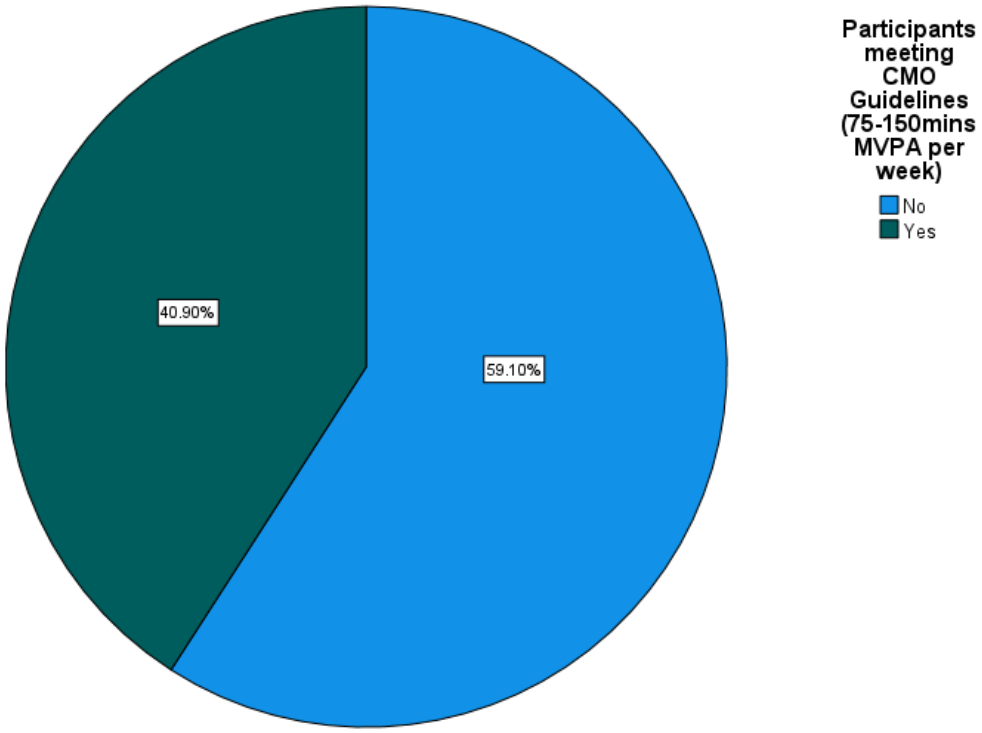


Figure 6.7 Percentage of participants meeting CMO PA guidelines (N=824)

Figure 6.7 above shows that more than half of participants (59%) did not meet the CMO PA guidelines.

6.6.2.2 Sedentary behaviour

Weekday

Figure 6.8 below shows time spent in weekday (MSQ) sitting domains

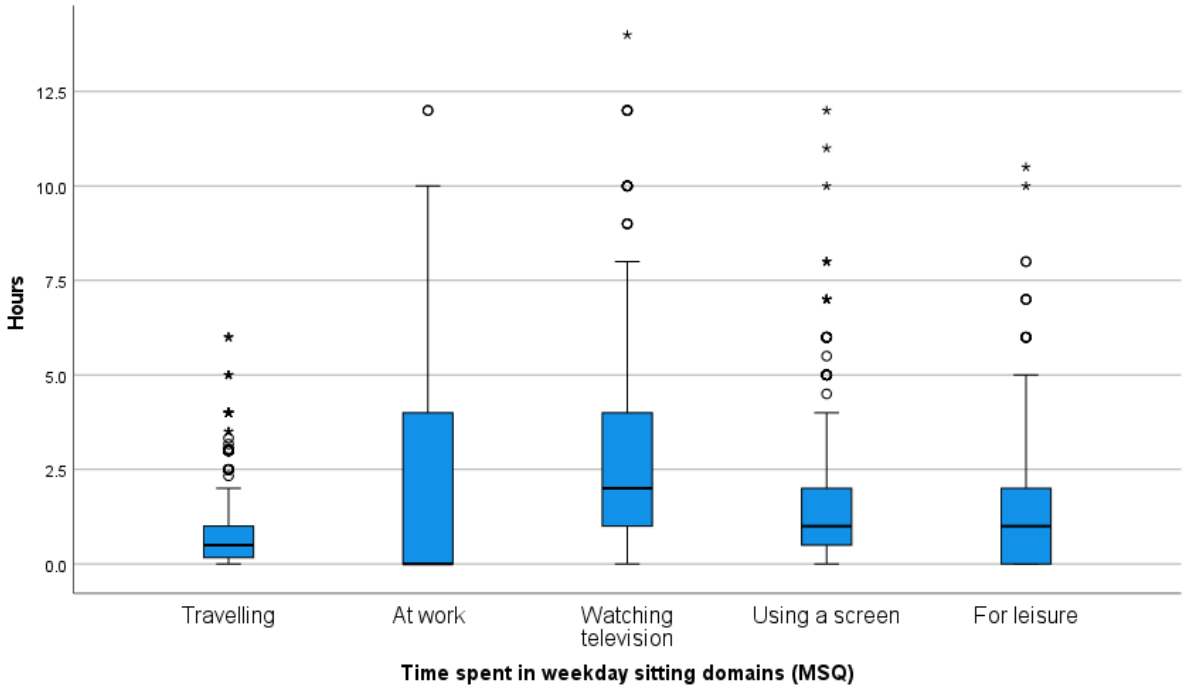


Figure 6.8 Self-reported time spent (hrs) in sitting domains (MSQ) on an average weekday (N=729)

Figure 6.8 shows that on an average weekday, participants self-reported spending more time sitting watching television than other domains (Md=2.00 IQR:1.00, 4.00); followed by sitting for leisure (Md=1.00, IQR:0.00, 2.00); using a screen (Md=0.50, IQR:1.00, 2.00) and travelling (Md=0.50, IQR:0.17, 1.00). Sitting at work showed the least amount of sitting time on average (Md=0.00, IQR:0.00, 4.00), but also showed the greatest variation.

The total time spent sitting on an average weekday is presented in Figure 6.9 below.

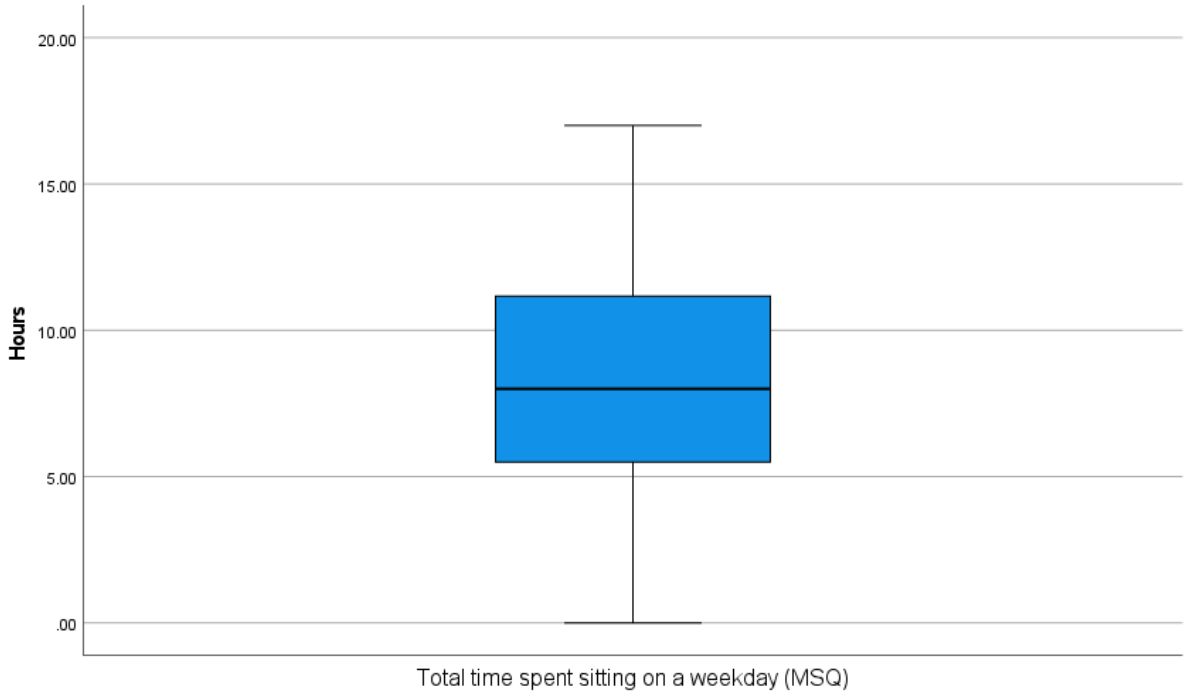


Figure 6.9 Self-reported time spent sitting on an average weekday (MSQ) (N=729)

Figure 6.9 shows that on an average weekday, participants self-reported spending on average 8hrs a day sitting (IQR: 5.50, 11.17)

Weekend day

Figure 6.10 below shows time spent in weekend day (MSQ) sitting domains.

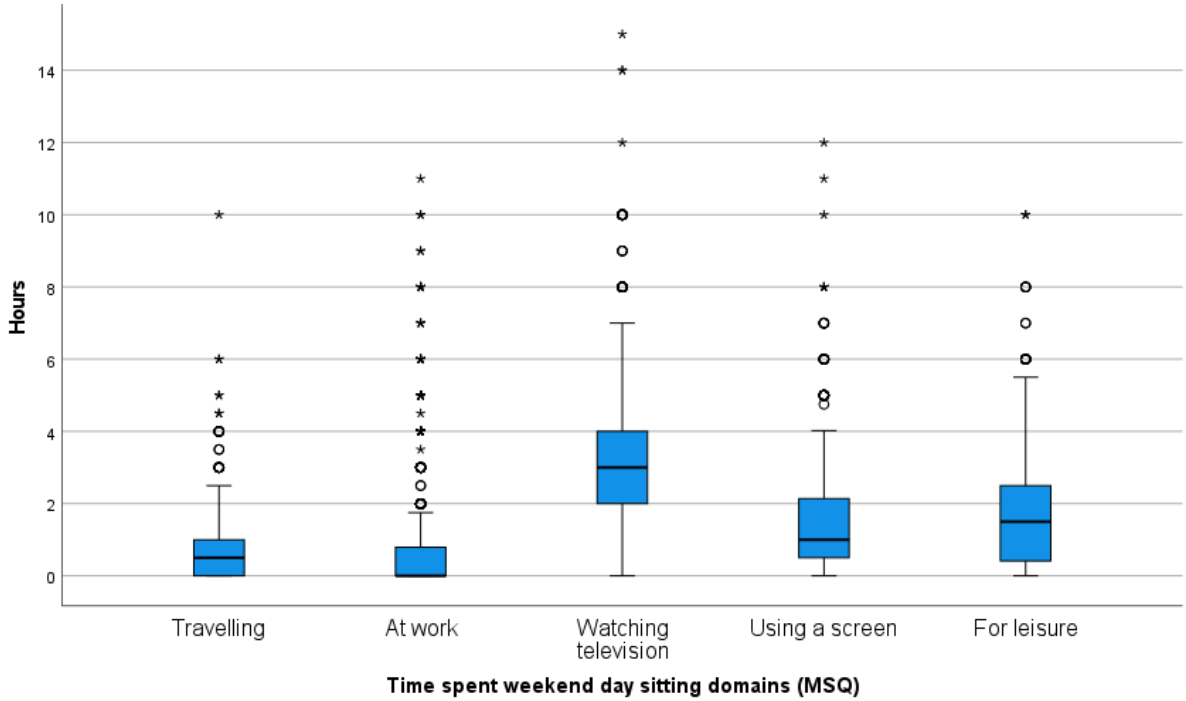


Figure 6.10 Self-reported time spent in sitting domains (MSQ) on an average weekend day (N=655)

Figure 6.10 shows that on an average weekend day, participants self-reported spending more time sitting watching television than other domains (Md=3.00 IQR:2.00, 4.00); followed by sitting for leisure (Md=1.5, IQR:0.33, 2.5); using a screen (Md=0.50, IQR: 1.00, 2.25) and travelling (Md=0.00, IQR:0.50, 1.00). Sitting at work showed the least amount of sitting time (Md=0.00, IQR:0.00, 0.83).

The total time spent sitting on an average weekend day is presented in Figure 6.11 below.

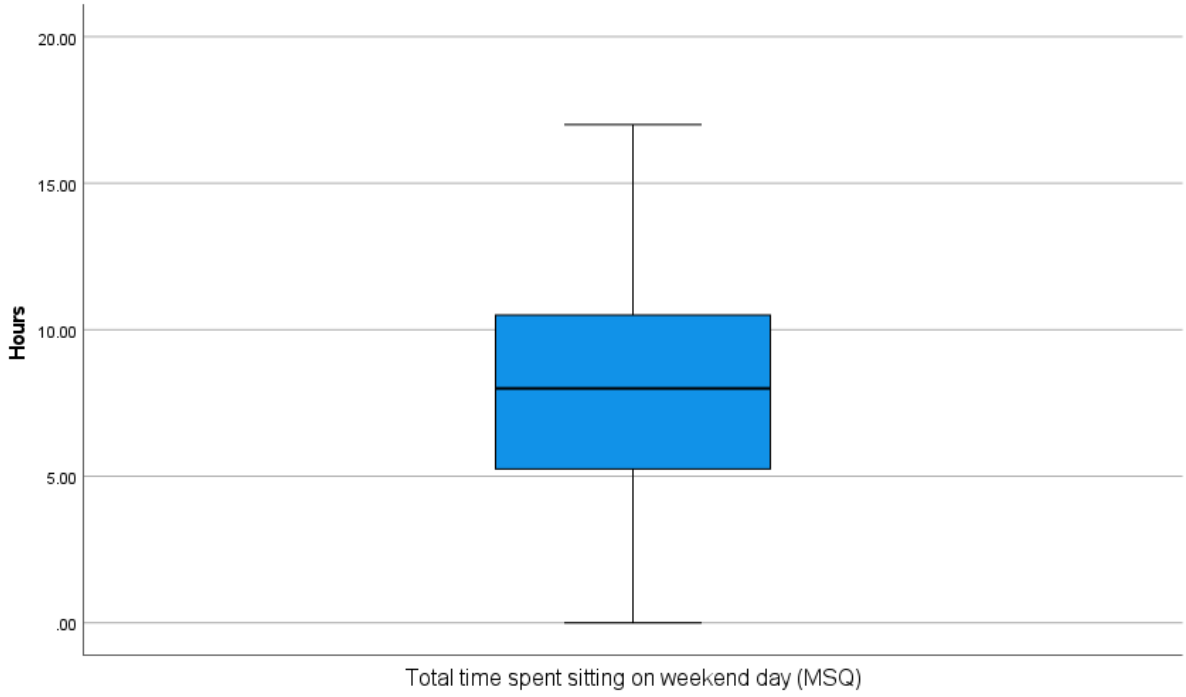


Figure 6.11 Self-reported time spent sitting on an average weekend day (MSQ) (N=655)

Figure 6.11 shows that on an average weekend-day, participants self-reported spending on average 8hrs a day sitting (IQR: 5.25, 10.5). Using Wilcoxon signed-ranks test, this was significantly lower than the time spent sitting on an average weekday presented in the previous section (Z=-2.795, n=623, p=0.005).

Total week

The total time spent sitting across the week is presented in Figure 6.12 below.

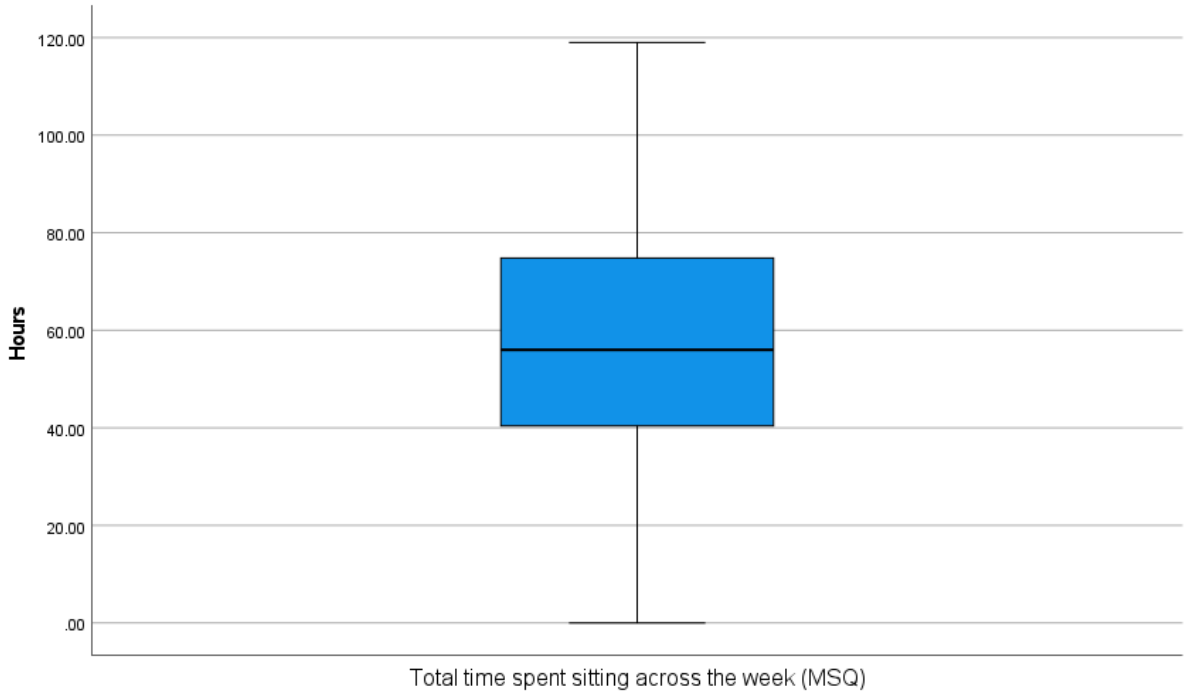


Figure 6.12 Total self-reported total time spent sitting (hrs) for the week (MSQ) (N=623)

Figure 6.12 shows that participants self-reported total sitting time for the 7-day period was on average 56.00hrs (IQR: 40.33, 74.83). Therefore, the average time spent sitting per day was 8.00hrs.

6.6.3 Self-reported 7-day recall mood symptoms

Objective 2: To gather self-reported 7-day recall depressive (BDI-19) and (hypo)manic (ASRM) mood symptoms in people living with BD.

6.6.3.1 Depression

The distribution of individual BDI-19 item scores (0-3) are shown in Table 6.3 below.

Table 6.3 Frequency of individual depression (BDI-19) symptoms

	Frequency and percentage of individual responses			
BDI-19 item	**0**	**1**	**2**	**3**
BDI-19-1: Feeling sad (N=1019)	613 (60%)	276 (27%)	88 (9%)	42 (4%)
BDI-19-2: Discouraged about the future (N=1019)	542 (53%)	289 (28%)	116 (11%)	72 (7%)
BDI-19-3: Feeling like a failure (N=1016)	519 (50%)	270 (26%)	170 (17%)	57 (6%)
BDI-19-4: satisfaction (N=1019)	451 (44%)	368 (36%)	139 (14%)	61 (6%)
BDI-19-5: Feeling guilty (N=1017)	592 (57%)	262 (25%)	111 (11%)	52 (5%)
BDI-19-6: Feeling punished (N=1016)	720 (70%)	146 (14%)	61 (6%)	89 (9%)
BDI-19-7: Disappointed in self (N=1020)	491 (48%)	407 (40%)	53 (5%)	69 (7%)
BDI-19-8: Self-critical (N=1017)	431 (42%)	385 (37%)	145 (14%)	56 (5%)
BDI-19-9: Thoughts of suicide (N=1012)	691 (67%)	263 (25%)	36 (4%)	22 (2%)
BDI-19-10: Crying (N=1017)	651 (63%)	183 (18%)	26 (3%)	157 (15%)
BDI-19-11: Feeling irritated (N=1014)	500 (49%)	378 (37%)	78 (8%)	58 (6%)
BDI-19-12: Interest in others (N=1014)	533 (52%)	300 (29%)	93 (9%)	88 (9%)
BDI-19-13: Decision making (N=1009)	499 (48%)	249 (24%)	225 (22%)	36 (4%)
BDI-19-14: Feeling unattractive (N=1013)	453 (44%)	301 (29%)	150 (15%)	109 (11%)
BDI-19-15: Ability to work (N=1017)	336 (33%)	381 (37%)	224 (22%)	76 (7%)
BDI-19-18: Appetite (N=1013)	737 (72%)	176 (17%)	80 (8%)	20 (2%)

	Frequency and percentage of individual responses			
BDI-19 Items	**0**	**1**	**2**	**3**
BDI-19-19: Weight loss (N=1005)	911 (88%)	57 (6%)	13 (1%)	24 (2%)
BDI-19-20: Health worries (N=1011)	544 (53%)	359 (35%)	83 (8%)	25 (2%)
BDI-19-21: Interest in sex (N=998)	354 (34%)	223 (22%)	160 (16%)	261 (25%)

Table 6.3 shows that individual BDI-19 items measuring severity of depressive symptoms were mostly clustered towards the less severe (left end) of the scale, and that the majority of scores were '0' or '1' or for all items, with the average score for each item also being '0' or '1.' BDI-19 item 21 showed the most variation in scores, and BDI-19 item 19 showed the least variation in scores.

Total scores for depression (using the BDI-19) for the 7-day period are shown in Figure 6.13 below (N=1007):

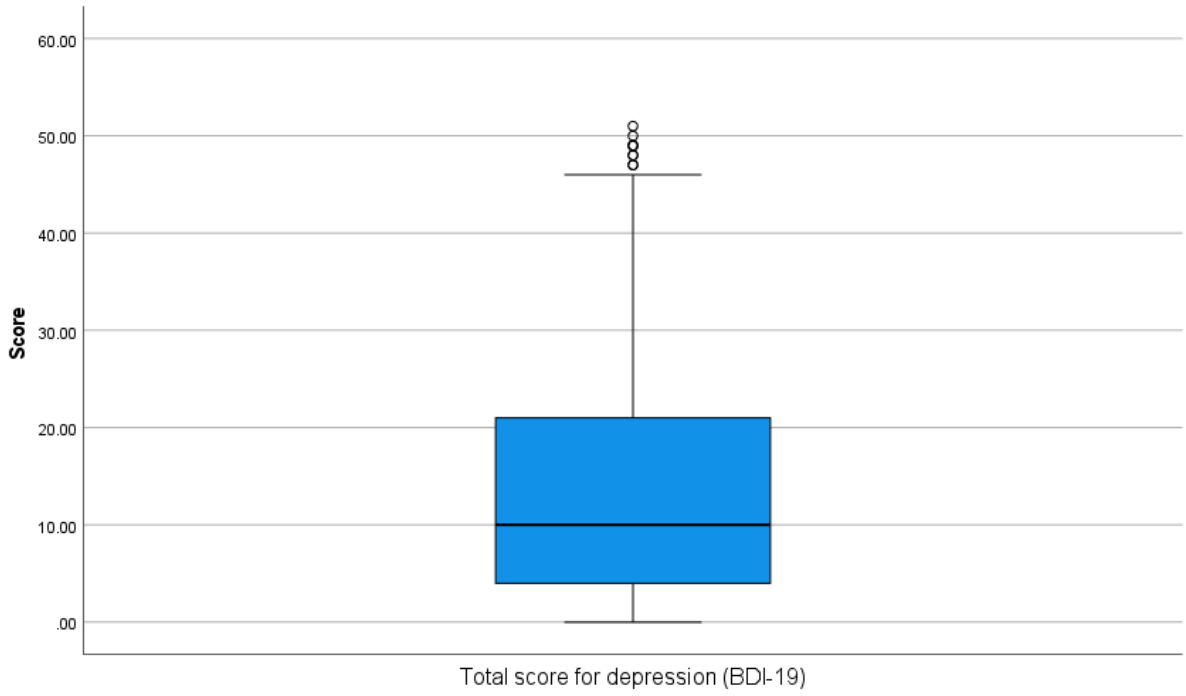


Figure 6.13 Distribution of depression (BDI-19) total scores (N=1007)

Figure 6.13 shows scores ranged from 0 to 51 out of the possible 57 (*Md*=10.00 *IQR*: 4.00, 21.00). Figure 6.13 also shows that 8 participants scored considerably higher than other participants, indicating they were experiencing a severe level of depression.

6.6.3.2 (Hypo)mania

The spread of individual ASRM item scores (0-4) are shown in Table 6.4 below.

Table 6.4 Distribution of individual (hypo)mania (ASRM) symptoms

	Frequency and percentage of individual responses				
ASRM item	**0**	**1**	**2**	**3**	**4**
ASRM1: Happiness (N=1016)	582 (57%)	294 (29%)	86 (8%)	40 (5%)	8 (1%)
ASRM2:Confidence (N=1014)	630 (61%)	275 (27%)	67 (7%)	32 (3%)	10 (1%)
ASRM3: Sleep (N=1007)	725 (70%)	146 (14%)	70 (7%)	45 (4%)	21 (2%)
ASRM4:Talking (N=1014)	616 (60%)	270 (26%)	68 (7%)	47 (5%)	13 (1%)
ASRM5:Activity (N=1015)	681 (66%)	227 (22%)	55 (5%)	36 (4%)	16 (2%)

Table 6.4 shows that all individual ASRM items measuring the severity of (hypo)manic symptoms were clustered towards the less severe (left end) of the scale (0-4), and that the majority of individual item scores were ‘1’ or less for all items, with the average score for each item being ‘0.’ All ASRM items showed little variation.

Total scores for (hypo)mania (using the ASRM) for the 7-day period are shown in Figure 6.14 below (N=1014).

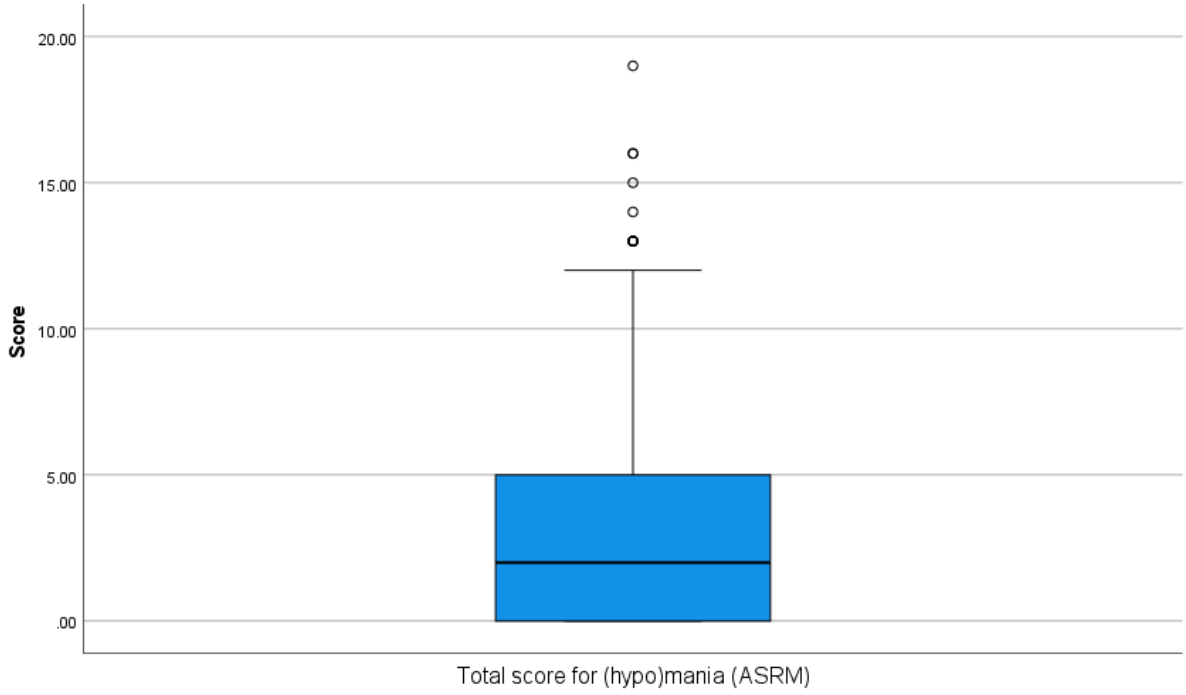


Figure 6.14 Distribution of (hypo)mania (ASRM) total scores (N=1014)

Figure 6.14 shows scores ranged from 0 to 19 out of the possible 20 (*Md*=2, *IQR*: 0, 5), and that scores clustered towards the lower end of the scale.

6.6.3.3 Mood state

Participant mood state for the 7-day period is presented in Figure 6.15 below, as measured and determined by the diagnostic cut-off values of the BDI-19 (Beck, 1988) and ASRM (Altman et al., 1997) criteria for (hypo)mania and depression severity in order to describe the mood state of the participant sample at time of participation.

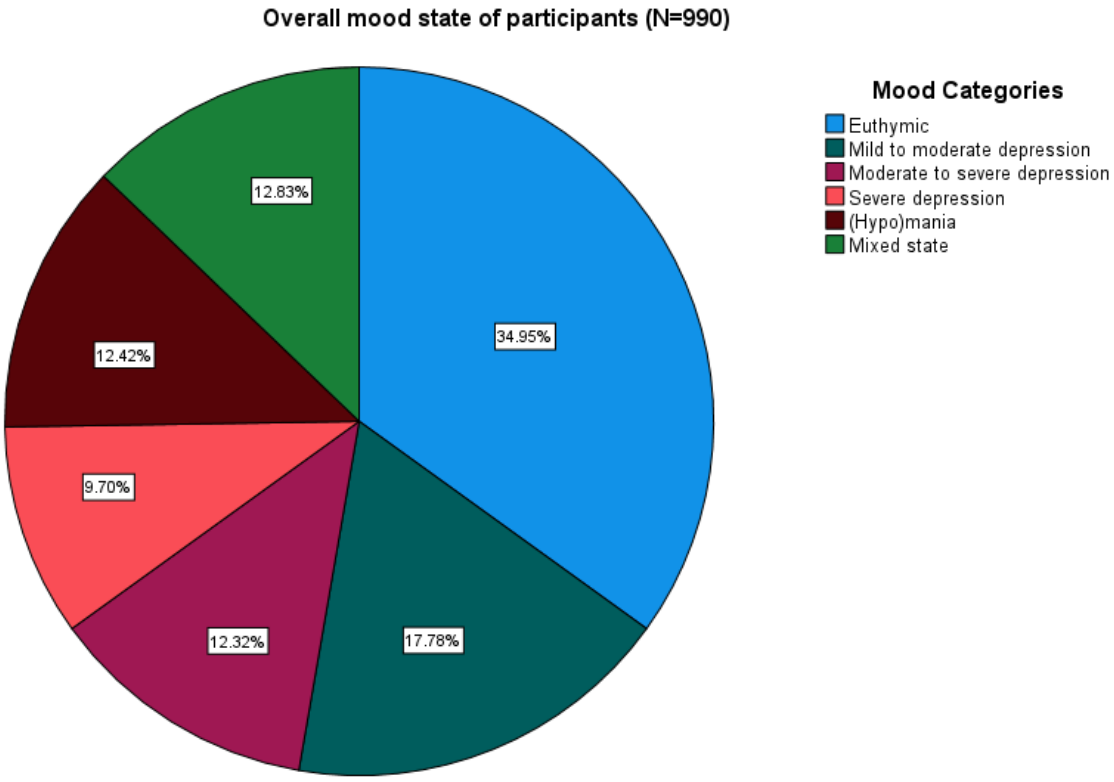


Figure 6.15 Mood state for participants using the BDI-19 and ASRM total scores to categorise mood (N=990)

Figure 6.15 shows that 40% of participants were experiencing a level of depression, with mild to moderate depression being the most common depression mood state (18%). Figure 6.15 also shows that 12% of participants were experiencing (hypo)mania; 13% were considered to be in a 'mixed state,' and 35% of participants were experiencing no significant mood symptoms as measured by the BDI-19 and ASRM at the time of participating and were therefore considered euthymic. Euthymia was the most common mood state overall for participants at the time of participation.

6.6.4 Relationships between self-reported physical activity, sedentary behaviour & mood symptoms

Objective 3: To explore the relationships between subjectively measured self-reported 7-day recall PA (IPAQ), SB (MSQ) and depressive (BDI-21) and (hypo)manic (ASRM) mood symptoms.

6.6.4.1 Relationships between self-reported physical activity & sedentary behaviour

The relationship between subjectively measured, self-reported PA as calculated from the IPAQ, and SB as calculated from the MSQ is shown below in Table 6.5.

Table 6.5 Correlations between self-reported PA (IPAQ) & sitting time (MSQ) (N=544)

	IPAQ Variables					
	IPAQ total time spent in vigorous intensity PA (hrs)	**IPAQ total time spent in moderate intensity PA (hrs)**	**IPAQ total time spent in MVPA (hrs)**	**IPAQ total time spent walking (hrs)**	**IPAQ total time spent in PA (hrs)**	**IPAQ total METS**
MSQ total week sitting time (hrs) (N=544)	*-0.089**	-0.077	*-0.095**	*-0.114***	*-0.141***	*-0.138***

**p<0.05, **p<0.01, ***p<0.001*

Table 6.5 above shows five significant negative associations of small strength between PA (IPAQ) and sitting time (MSQ). The strongest association observed is a negative association of small strength between total time spent in PA (IPAQ) and total week sitting time (MSQ).

6.6.4.2 Relationships between self-reported physical activity & depression symptoms

Table 6.6 below shows the relationships between self-reported PA (IPAQ) and depressive (BDI-19) mood symptoms.

Table 6.6 Correlations between self-reported PA (IPAQ) & depression symptoms (BDI-19)

	BDI-19 items (1-10)										
IPAQ Variables	**Feeling sad (N=819)**	**Discouraged about the future (N=819)**	**Feeling like a failure (N=818)**	**satisfaction (N=820)**	**Feeling guilty (N=819)**	**Feeling punished (N=820)**	**Disappointed in self (N=821)**	**Self-critical (N=820)**	**Thoughts of suicide (N=815)**	**Crying (N=817)**	**Number of significant correlations**
IPAQ total time spent in vigorous intensity PA (hrs)	*-0.105***	*-0.131****	*-0.094***	*-0.156****	-0.051	-0.058	*-0.126****	-0.061	*-0.096***	-0.064	6
IPAQ total time spent in moderate intensity PA (hrs)	-0.067	*-0.107***	*-0.071**	*-0.132****	-0.046	-0.024	*-0.091***	-0.056	-0.064	-0.011	4
IPAQ total time spent in MVPA (hrs)	*-0.097***	*-0.132****	*-0.090***	*-0.166****	-0.055	-0.037	*-0.115****	-0.068	*-0.080**	-0.040	6
IPAQ total time spent walking (hrs)	*-0.148****	*-0.198****	*-0.111***	*-0.174****	*-0.072**	*-0.070**	*-0.138****	*-0.069**	*-0.090***	*-0.075**	10
IPAQ total time spent in PA (hrs)	*-0.149****	*-0.188****	*-0.120****	*-0.189****	*-0.071**	-0.065	*-0.148****	*-0.0818**	*-0.094***	*-0.071**	9
IPAQ total METS	*-0.150****	*-0.189****	*-0.122****	*-0.197****	*-0.076**	*-0.070**	*-0.154****	*-0.086**	*-0.097***	*-0.072**	10

	BDI-19 items (11-21, excluding 16 & 17) & total score										
IPAQ Variables	**Feeling irritated (N=815)**	**Interest in others (N=815)**	**Decision making (N=811)**	**Feeling unattractive (N=815)**	**Ability to work (N=818)**	**Appetite (N=815)**	**Weight loss (N=810)**	**Health worries (N=815)**	**Interest in sex (N=808)**	**BDI-19 total score (N=813)**	**Number of significant correlations**
IPAQ total time spent in vigorous intensity PA (hrs)	-0.066	*-0.092***	*-0.112***	*-0.106***	*-0.183****	*-0.125****	*-0.075**	*-0.128****	-0.059	*-0.143****	8
IPAQ total time spent in moderate intensity PA (hrs)	-0.044	*-0.085***	*-0.076**	*-0.101***	*-0.124****	*-0.088***	0.006	*-0.090***	-0.006	*-0.102***	7
IPAQ total time spent in MVPA (hrs)	-0.058	*-0.101***	*-0.101***	*-0.112***	*-0.172****	*-0.131****	-0.049	*-0.121***	-0.020	*-0.132****	7
IPAQ total time spent walking (hrs)	-0.062	*-0.134****	*-0.086***	*-0.125****	*-0.168****	*-0.080**	-0.046	*-0.145****	-0.048	*-0.147****	7
IPAQ total time spent in PA (hrs)	*-0.074**	*-0.127****	*-0.091***	*-0.141****	*-0.188****	*-0.099***	-0.064	*-0.150****	-0.034	*-0.157****	8
IPAQ total METS	*-0.078**	*-0.126****	*-0.099***	*-0.147****	*-0.200****	*-0.113***	*-0.075**	*-0.153****	-0.040	*-0.165****	9

**p<0.05, **p<0.01, ***p<0.001*

Table 6.6 above highlights several significant negative associations between PA (IPAQ) engagement and symptoms of depression (BDI-19) during the 7-day recall period, all of small strength. All PA (IPAQ) variables were negatively associated with the total score for depression (BDI-19). The total METS for the 7-day recall period was negatively associated with the most depression symptoms, all except *'changes in interest in sex,'* which was also the only symptom to show no significant association with any PA (IAPQ) variables. The strongest association observed was a small strength negative association between total METs and *'ability to work.'*

6.6.4.3 Relationships between self-reported physical activity & (hypo)mania symptoms

Table 6.7 below shows the relationship between self-reported weekly totalled PA obtained from the IPAQ with (hypo)mania symptoms (ASRM).

Table 6.7 Correlations between self-reported PA (IPAQ) & (hypo)mania (ASRM) symptoms

	ASRM Items						
IPAQ variables	**Happiness N=819**	**Confidence N=818**	**Sleep N=814**	**Talking N=816**	**Activity N=818**	**ASRM total score N=819**	**Number of significant correlations**
IPAQ total time spent in vigorous intensity PA (hrs)	0.065	*0.087***	-0.015	0.027	*0.140****	*0.076**	3
IPAQ total time spent in moderate intensity PA (hrs)	0.024	0.007	-0.026	-0.007	*0.088****	0.026	1
IPAQ total time spent in MVPA (hrs)	0.059	0.058	-0.016	0.018	*0.144****	*0.071**	2
IPAQ total time spent walking (hrs)	*0.085***	0.065	0.055	0.003	*0.103***	0.066	2
IPAQ total time spent in PA (hrs)	*0.096**	*0.092***	0.011	0.030	*0.169****	*0.106***	4
IPAQ total METS	*0.096***	*0.098***	0.008	0.031	*0.177****	*0.108***	4

**p<0.05, **p<0.01, ***p<0.001*

Table 6.7 above shows several significant positive associations of PA engagement (IPAQ) and (hypo)mania symptoms (ASRM) during the 7-day recall period. All associations were small in strength. The strongest association observed is a small

strength, positive association of total METs and *'increased activity.'* This symptom was also the only (hypo)mania symptom to significantly correlate with all PA (IPAQ) variables.

6.6.4.4 Relationships between self-reported sedentary behaviour & depression symptoms

Table 6.8 below shows the relationship between weekly totalled time spent sitting (MSQ) and depressive (BDI-19) mood symptoms.

Table 6.8 Correlations between self-reported sitting time (MSQ) & depression symptoms (BDI-19)

	BDI-19 items (1-10)										
	Feeling sad (N=620)	**Discouraged about the future (N=622)**	**Feeling like a failure (N=620)**	**Satisfaction (N=621)**	**Feeling guilty (N=620)**	**Feeling punished (N=621)**	**Disappointed in self (N=622)**	**Self-critical (N=622)**	**Thoughts of suicide (N=615)**	**Crying (N=620)**	**Number of significant correlations**
Total time spent sitting (MSQ)	0.028	0.053	0.053	0.067	0.035	0.061	*0.084**	*0.094**	0.061	0.068	2
	BDI-19 items (11-21, excluding 16 & 17) & total score										
	Feeling irritated (N=618)	**Interest in others (N=619)**	**Decision making (N=616)**	**Feeling unattractive (N=619)**	**Ability to work (N=620)**	**Appetite (N=619)**	**Weight loss (N=613)**	**Health worries (N=618)**	**Interest in sex (N=614)**	**BDI-19 total score (N=619)**	**Number of significant correlations**
Total time spent sitting (MSQ)	0.008	0.030	0.034	0.076	0.021	-0.011	-0.010	0.042	0.044	0.074	0

**p<0.05, **p<0.01, ***p<0.001*

Table 6.8 above shows two significant, small strength positive associations between total sitting time (MSQ) and depression symptoms (BDI-19): *'disappointment in self'* and *'being self-critical.'*

6.6.4.5 Relationships between self-reported sedentary behaviour & (hypo)mania symptoms

Table 6.9 below shows the relationship between weekly totalled time spent sitting (MSQ) and (hypo)manic (ASRM) mood symptoms.

Table 6.9 Correlations between self-reported time spent sitting (MSQ) & (hypo)mania symptoms (ASRM)

	ASRM items					
	Happiness (N=621)	**Confidence (N=619)**	**Sleep (N=615)**	**Talking (N=619)**	**Activity (N=621)**	**ASRM total score (N=620)**
MSQ total week sitting time (hrs)	0.043	0.074	0.037	*0.102***	0.046	0.068

**p<0.05, **p<0.01, ***p<0.001*

Table 6.9 above shows one positive, small strength association between total week sitting time (MSQ) and 'talking more than usual.'

6.6.4.6 Relationships between self-reported time spent in sitting domains & depression & (hypo)mania symptoms

Objective 4: to explore relationships between subjectively measured self-reported 7-day recall time spent in sitting domains and depressive (BDI-19) and (hypo)mania (ASRM) symptoms

Table 6.10 below shows the relationship between weekly totalled time spent in various sitting domains (MSQ) with depressive and (hypo)manic mood symptoms.

Table 6.10 Correlations between self-reported time spent in sitting domains (weekly totalled) (MSQ) & depression (BDI-19) & (hypo)mania (ASRM) total scores

Time spent in sitting domains (weekly totals) (MSQ)	**BDI-19 total score (depression) (N=619)**	**ASRM total score ((hypo)mania) (N=620)**
Sitting travelling	-0.065	*0.150***
Sitting at work	*-0.170***	-0.006
Sitting watching television	*0.150***	*0.079**
Sitting using a screen	*0.106***	0.064
Sitting for leisure	*-0.117***	*0.079**

**p<0.05, **p<0.01, ***p<0.001*

Table 6.10 above shows several significant associations between time spent in sitting domains (MSQ), and depression (BDI-19) and (hypo)mania (ASRM) total scores, all of small strength. Sitting for travel was positively associated with (hypo)mania symptom severity. Sitting watching television was positively associated with both depression and (hypo)mania symptom severity. Sitting using a screen was positively associated with depression, and sitting for leisure was negatively associated with depression symptom severity, and positively associated with (hypo)mania symptom severity.

6.6.5 Identifying potential confounding factors in the relationships between physical activity, sedentary behaviour & self-reported mood symptoms

Objective 5: To identify potential confounding factors in the relationships between self-reported PA (IPAQ), SB (MSQ), and depressive (BDI-19) and (hypo)manic (ASRM) mood symptoms.

The variables presented in the participant description section were explored further to identify if there were any significant differences between grouping variables *(gender, BD sub-type, and physical health co-morbidities)* as well as any associations between continuous variables *(age, age of BD illness onset (yrs), length of BD illness (yrs), average number of (hypo)manic episodes per illness year, and average number of depressive episodes per illness year)* with the subjectively measured PA and SB, and the self-reported mood symptoms. This was done to explore whether any significant associations identified in sections 6.7.4 to 6.7.4.6 could be explained by these factors. Due to the number of variables and analyses carried out, this section presents the analysis of factors which were explored as confounders. All other analyses, including the non-significant analyses, and analyses which only showed a significant difference/association with either PA, SB or mood (and therefore were not considered to be confounding factors) are presented in Appendix Q.

Bipolar disorder sub-type

There were significant differences between those with BDI and BDII on their self-reported total time spent in vigorous intensity PA (IPAQ), total time spent in moderate intensity PA (IPAQ), total week sitting time (MSQ), and the total score for depression (BDI-19). These differences are shown below in Table 6.11.

Table 6.11 Differences of BD sub-type on PA & mood variables

PA & Mood variables	Differences between those with BDI and BDII (median & interquartile range)
Total weekly time spent in vigorous PA (hrs) (IPAQ)	*U=68772.50** *1=548* Md=0.00 (IQR: 0.00, 2.00) *2=276* Md=0.00 (IQR: 0.00, 3.00)
Total weekly time spent in moderate PA (hrs) (IPAQ)	U=68896.50* 1=548 Md=0.00 (IQR: 0.00, 2.00) 2=276 Md=0.50 (IQR: 0.00, 3.38)
Depression (BDI-19 total score)	U=93690.50*** 1=685 Md=9.00 (IQR: 4.00, 18.00) 2=322 Md=13.50 (IQR: 4.00, 24.00)

1= BDI participants, 2= BDII participants
**p<0.05, **p<0.01, ***p<0.001*

Given the above identified significant differences between those with BDI and BDII, BD sub-type was considered a potential confounding factor in the analyses presented previously in Table 6.6 (page 325) which identified significant relationships between time spent in vigorous PA (IPAQ) and time spent in moderate PA (IPAQ) with the total depression score (BDI-19). These analyses are therefore presented separately by BD-sub-type below in Table 6.12:

Table 6.12 Associations between PA (IPAQ) & depression (BDI-19) split by BD sub-type

PA and depression correlations	BD Sub-type	
	BDI (N=540)	**BDII (N=273)**
Total time spent in vigorous PA (IPAQ) & total depression score (BDI-19)	*-0.132***	*-0.185***
Total time spent in moderate PA (IPAQ) & total depression score (BDI-19)	*-0.093**	*-0.158***

**p<0.05, **p<0.01, ***p<0.001*

Table 6.12 above shows four significant, negative, small strength associations between time spent in vigorous intensity PA, and time spent in moderate intensity PA with the total score for depression; and shows that BD sub-type was not a confounding factor in the relationship between time spent in vigorous and moderate PA with the total depression score.

Hypertension

There were also significant differences between participants with and without a history of hypertension on their time spent in vigorous PA (IPAQ), total time spent in PA, and total depression score (BDI-19). These differences are shown in Table 6.13 below.

Table 6.13 Differences in those with & without a history of hypertension on PA & mood

PA & mood	Hyper-tension (median & interquartile range)
Total weekly time spent in vigorous PA (hrs) (IPAQ)	U=42431.50** Y=171 Md=0.00 (IQR:0.00, 1.00) N=561 Md=0.00 (IQR:0.00, 2.50)
Total weekly time spent in PA (hrs) (IPAQ)	U=42339.00* Y=171 Md=5.50 (IQR:1.67, 14.00) N=561 Md=7.00 (IQR:3.00, 14.00)
Depression total score (BDI-19)	U=64525.50** Y=215 Md=12.00 (IQR:5.00, 22.00) N=682 Md=10.00 (IQR:4.00, 19.00)

Y=participants with hypertension, N=participants without hypertension
**p<0.05, **p<0.01, ***p<0.001*

Given the above identified significant differences between those with and without a history of hypertension, a history of hypertension was considered a potential confounding factor in the analyses from Table 6.6 (page 325) which identified significant relationships between time spent in vigorous PA (IPAQ) and time spent in total PA (IPAQ) with the total depression score (BDI-19), and so these analyses are presented separately by those with and without a history of hypertension below in Table 6.14.

Table 6.13 Associations between PA (IPAQ) & depression (BDI-19) split by those with & without a history of hypertension

PA and depression correlations	**History of hypertension**	
	Yes (N=169)	**No (N=556)**
Total time spent in vigorous PA (IPAQ) & total depression score (BDI-19)	*-0.168**	*-0.116***
Total time spent in PA (IPAQ) & total depression score (BDI-19)	*-0.191**	*-0.140***

**p<0.05, **p<0.01, ***p<0.001*

Table 6.14 above shows four significant, small strength negative associations between total time spent in vigorous intensity PA and total time spent in PA with the total score for depression, and shows that a history of hypertension was not a confounding factor in the relationship between total time spent in PA or total time spent in vigorous PA and depression.

6.6.6 Results summary

This study has provided some important results for understanding the relationships between PA, SB and BD mood symptoms. The key results are highlighted and summarised below.

- On average participants spent 6hrs a week engaged in a form of PA. The most engaged with form of PA across the 7-day recall period was walking (3hrs 30mins) followed by moderate intensity PA (0hrs), and the least amount of time spent in vigorous intensity PA (0hrs).
- On average, participants spent just under an hour in a form of PA per day, however just over half of participants (59%) did not meet the recommended CMO guidelines of 75mins of vigorous or 150mins of moderate intensity PA per week.
- Overall, participants self-reported spending more time in SB than any form of PA, both on an average day (8hrs) and across the total week (56hrs).
- Participants also self-reported spending more time sitting watching television than in any other sitting domain, regardless of whether this was a weekday (3hrs) or weekend-day (3hrs), and there was little variation in the time spent in various sitting domains between weekdays and weekend days. Time spent sitting at work showed the highest variation, with more time spent sitting at work on weekdays than weekend days.
- Negative associations were observed between sitting time (MSQ) and time spent in PA (IPAQ).

- All significant associations between PA (IPAQ) and (hypo)mania symptoms (ASRM) were positive, and all significant associations between PA (IPAQ) and depression symptoms (BDI-19) were negative.
- All significant associations between SB (MSQ) and (hypo)mania symptoms (ASRM) were positive, and all significant associations between SB (MSQ) and depression symptoms (BDI-19) were also positive.
- There were more significant associations between PA (IPAQ) and depression (BDI-19) and (hypo)mania (ASRM), than SB (MSQ) and depression (BDI-19) and (hypo)mania (ASRM).
- Significant associations were observed between time spent in sitting domains and mood. Sitting watching television was positively associated with both depression and (hypo)mania. Sitting for leisure was negatively associated with depression, and positively associated with (hypo)mania. Sitting for travel was positively associated with (hypo)mania. Sitting at work was negatively associated with depression and sitting using a screen was positively associated with depression.
- There were significant differences between those with BDI and BDII and those with and without hypertension on both PA engagement and total depression score, however these differences did not confound the relationship between PA and mood symptoms.

6.7 Discussion

This section provides a discussion of the results of this study, and then reflects on the study's strengths and limitations. A full synthesis of the results from all three studies is provided in the discussion chapter, chapter seven.

The current study included 1031 participants living with BD, 824 of whom had usable data on their PA engagement self-reported from the IPAQ. This is considerably more than previous studies investigating PA in BD which also used the IPAQ as a subjective measurement of PA: Vancampfort et al., (2016d) recruited 22 participants with BD; Vancampfort et al., (2015f) recruited 69 participants; Melo et al., (2019)'s study included 80 participants; Fellendorf et al., (2017)'s study included 120 participants; Folke la Karottki et al., (2020) study included 227 participants; and Masa-Font et al., (2015)'s study included 240 participants. Kilbourne et al., (2007) did recruit 2032 participants with BD, but included no measurement of mood and a very brief measure of exercise only, rather than an established tool such as the IPAQ.

In their comparison of physical fitness between those living with BD, schizophrenia and healthy controls, Vancampfort et al., (2016d) reported on IPAQ MET values to provide an indication of subjectively measured physical fitness. They reported people with BD as being more physically active, or 'fit' than those with schizophrenia, but not controls, reporting the 22 participants with BD as using 1271.6 METS (using the mean value) during the recall period, whereas the current study found this to be 1485.00 METS (using the median value).

Melo et al., (2019) reported higher PA levels in people with BD using the IPAQ than the current study, reporting 52.5% of their 80 participants as being 'physically active,'

and 47.5% as being ‘sedentary.’ However, they did not report the number of participants in the three PA categories suggested within the IPAQ scoring protocol (low, medium or high) as the current study did. Throughout the Melo et al., (2019) study, physical inactivity and SB are regarded as the same thing despite being separate constructs, as it is possible to be physically inactive (not meeting CMO guidelines 2015, 2019) but not predominately sedentary, e.g. engaging in standing, or ‘stationary behaviour’ (Tremblay et al., 2017). The current study avoided this issue by having measured PA and SB separately, and not relying on the IPAQ sitting question as its measure of SB and reporting on each construct separately. This study also reported on the number of people considered to be engaging in ‘low’ ‘medium’ or ‘high’ levels of PA according to the IPAQ in comparison to those meeting the CMO PA guidelines, showing that over half of participants did not meet the CMO guidelines. However, approximately two thirds of participants were still considered to engage in medium or high levels of PA weekly. This indicates that although people with BD may not be engaging in as much vigorous or moderate intensity PA as is recommended, they are still making effort to engage in PA weekly.

Fellendorf et al., (2017) reported significant differences between participants of varying PA levels (defined by IPAQ) on their performance on cognitive tasks, but not mood, and these differences were further characterised by gender (males: low=17.2%, medium=37.5% and high=45.3%, females: low=26.8%, medium=25.0%, high=48.2%). The proportion of participants considered as being highly physically active, like Melo et al., (2019), is higher than previous research (Janney et al., 2014; Stubbs et al., 2016; Vancampfort et al., 2016a) and the current study. However, it is worth noting that although Fellendorf et al., (2017) and Melo et al., (2019) included the same measurements of (hypo)mania symptoms (Young Mania Rating Scale

(Young et al., 1978)); and depression symptoms (Hamilton scale (Hamilton, 1960)); these were included to ensure only euthymic patients were recruited, (although they each used different cut off scores to determine this) and so unsurprisingly Fellendorf et al., (2017) found no significant differences between the mood scores of those in different PA level categories. Melo et al., (2019) did not report on any relationship between PA and mood, and excluded 86 participants on the basis of not being euthymic. Furthermore, both studies recruited patients from inpatient and outpatient psychiatric settings, and so their samples may not be representative of typical 'free living' PA within the general BD population, especially if only euthymic participants were included. The current study has provided essential information on the relationships between PA, SB and BD mood symptoms as well as exploring potential confounding factors in these relationships implied from the above studies (such as gender) in a wider, larger population sample. Only depression symptom severity (using BDI-19) was significantly different between males and females in the current study (see Appendix Q). However, study two found males engaged in more MVPA, and had higher ratings of 'elation' and 'energy,' but that the positive relationship observed between MVPA and 'elation' and 'energy' was only significant in females. The current study however did find that MVPA (IPAQ) positively correlated with (hypo)mania (ASRM), but that there was no evidence of gender being a confounding factor in this relationship. This difference may be due to the use of subjective rather than device-based measures being used in this study.

The current study found that participants self-reported spending approximately 8hrs a day sitting using the MSQ on both weekdays and weekend-days. This is approximately 2hrs less than the average time in SB obtained from the ActivPAL3 in study two (10hrs), and of weekday (9hrs, 25mins) and weekend day (9hrs) time

spent sitting (MSQ) responses from study two. Eight hrs a day sitting is also approximately 2.5hrs less than Vancampfort et al., (2016a) (10hrs 13mins) and Vancampfort et al., (2017b)'s (10hrs 15mins) systematic reviews including both subjective and device-based measurements of SB. It is possible that in this larger population study, the sitting time was less than that of the participants in study two, however this may also be due to the common observation in subjective explorations of SB, that SB is often either over or underestimated in large studies when compared to device-based measures (Prince et al., 2017; 2020).

Furthermore, much of the previous research has included inpatients or recovering outpatients recruited via clinical settings, who may exhibit different SB than those who participated in the current study (Fellendorf et al., 2017; Krane-Gartiser et al., 2018a; Melo et al., 2019; Stanton & Happell, 2014; Vancampfort et al., 2017b; Vancampfort et al., 2016d). In addition, 49% of participants responded to the 'sitting at work' item with a response above '00:00' for either weekday and/or weekend days in this study, compared with 33% of participants in study two, and sitting at work showed the greatest variation in reported weekday and weekend-day sitting times for both this study and study two. This may be a further explanation for the observed differences in total sitting times between studies, as employment may provide added structure and ease of recall for sitting behaviours, as well as determining the time spent sitting in that domain.

Increases in 'activity' is a criterion for a (hypo)manic mood state (APA, 2013), although, there is no specificity as to whether this relates to physical or non-physical activity in the DSM diagnostic criteria (APA, 2013). Within the current study, all PA variables (IPAQ) positively correlated with item-5 'increase in activity' on the ASRM which measures (hypo)manic mood symptoms. Although it is acknowledged these

correlations were small, it is nonetheless evidence of participant perception of increased ‘activity’ being related to an increase in their *physical* activity. In relation to the findings of study one which explored participants perceptions of PA and SB in relation to mood symptoms, this is an interesting finding as participants struggled at times to distinguish between general activity and PA. This is indicative of the complexity of (hypo)mania as a mood state, and the difficulty in defining what is considered to be a mood *symptom*, what is a potential *influencer or trigger* of mood, and what has changed *due* to the shift in mood. This complexity and uncertainty is the foundation of study one’s main theme ‘PA and SB changes as an early warning sign’ for mood changes, which captured the difficulty participants had in describing the relationship between PA, SB and their mood, and how the impact of PA can be perceived as both ‘positive’, and ‘negative’ depending on their mood.

The above is in contrast to Branco et al., (2014) who found no association between PA and the presence of (hypo)manic mood symptoms as measured using the IPAQ and the Mini International Neuropsychiatry Interview, proposing that it is agitation rather than the (hypo)manic state that contributes to an increase in PA, a feature of mood often associated with mixed state (APA, 2013) (although this can be an independent feature of depression and (hypo)mania also). This is arguably an unsupported statement considering that the direction between the relationship of PA and mood had not been established in BD, and so it is not clear whether agitation or (hypo)mania actually *causes* increased PA. Furthermore, only 9% of the participant sample were considered (hypo)manic, and 18% were considered to be depressed in the Branco et al., (2014) study which may explain the absence of this association as the study was not specifically aiming to explore PA in BD, but PA in mood disorders and so included participants with depression *and* BD which may have skewered the

results. The study one interviews provided support of the theory adopted by Branco et al., (2014) that agitation may 'fuel PA,' by describing anger as fuelling PA engagement, although this was not observed in study two as there were no significant associations between PA and anger. Participants however also reflected on the sense of elation and euphoria (typically characteristic of (hypo)mania)) in study one as keeping them physically active which was discussed under the subthemes of the 'negative impact' of PA, and 'increasing PA levels'. This is something which was mirrored in the study two findings regarding the relationship between daily ratings of 'elation' and feeling 'energetic' and daily device-measured MVPA, in females only. A further critique on Branco et al., (2014)'s handling of PA data from the IPAQ, is the classification into simply 'active' or 'not active' based on 150mins of PA per week. This categorisation means that participants reporting 75mins of vigorous PA per week (who therefore meet the CMO guidelines) are regarded as 'not active.' Considering the observed relationships between vigorous and moderate PA with (hypo)mania in this study, this is a severe limitation.

In regards to symptoms of depression (measured using the BDI-19 in the current study) the results supported previous research also showing a negative association with low PA levels and high levels of depression (Bélair, Kohen, Kingsbury, & Colman, 2018; Scarapicchia et al., 2014; Vancampfort et al., 2018a; Weinstein, Koehmstedt, & Kop, 2017; Yun et al., 2020), as well as high SB levels being positively associated with symptoms of depression (Bélair et al., 2018; Faulkner & Biddle, 2013; Teychenne et al., 2015; Zhai et al., 2015), but only two symptoms of depression were significantly associated with SB: *'disappointed in self'* and being *'self-critical.'*

Furthermore, previous research has already provided evidence of more time spent sitting watching television being associated with increased SB (Mansoubi et al., 2014) and depressive symptoms (Hallgren et al., 2019; Teychenne et al., 2010), however the current study highlighted that sitting watching television was the most commonly reported SB domain for both weekday and weekend-days in people living with BD, and the total time spent watching television was positively associated with both depression and (hypo)mania symptom severity. This could be due to efforts to counteract (hypo)mania, and/or the type of television programme being watched, as a participant in study one highlighted that watching television can be helpful for calming (hypo)mania, but that if this was an action film, it would be counterproductive and make (hypo)mania worse. This is important information for interventions aiming to reduce SB in BD, particularly since Hallgren et al., (2019) found that symptoms of depression were associated with mentally passive SB, and mentally 'active' SB may actually be helpful for depressive symptoms. Sitting for leisure was negatively associated with depression, but positively associated with (hypo)mania. (Hypo)mania scores were also positively associated with more time spent sitting for travel which may be indicative of characteristics such as excessive spending (e.g., shopping/online shopping), socialising, researching topics of interests, and engaging in projects and activities (not necessarily PA) due to the SB being mentally 'active' i.e. goal orientated activity (DSM-5 criteria for a (hypo)manic episode). It is also possible that the positive associations observed between SB and (hypo)mania are due to a reduced need for sleep when in this mood state, and so may exhibit more time spent sitting due to spending more time awake. In sum, although the observed associations between SB domains and mood symptom severity in the current study

were small in strength, this provides evidence that the type of sitting engaged with may be important in relation to mood symptoms.

6.7.1 Strengths

This study had a large sample size of 1031 participants which was considerably larger than the majority of previous explorations of PA and/or SB in people living with BD. It provides the only current exploration of time spent in SB domains in BD using the MSQ, and the only one to explore SB domains in relation to mood specifically in BD. This study is, to the researcher's knowledge, also the largest study exploring PA in BD using the IPAQ, and one of few to also include a measure of BD mood symptoms.

This study has overcome limitations identified in previous research by exploring both PA and SB specifically in BD (rather than mixed population samples where BD is often underrepresented), by including participants with both BDI and BDII (as those with BDII are also often underrepresented); and including measures of both depressive and (hypo)manic symptoms, whereas previous research has largely focused on depressive symptoms only.

As the questionnaire was posted/emailed to participants for them to complete at a time most convenient to them and in the comfort of their own home, a further strength of this study was that it was less intrusive than study one and study two and so the sample is likely to be more representative. This allowed for uninfluenced self-reported data to be collected, and relationships between PA, SB and mood to be explored in people who could be considered to be experiencing depression, (hypo)mania, mixed state, and euthymia. In addition, this study used a population-based sample rather than recruiting directly from inpatient or outpatient clinics, and

so provides a greater representation of the current UK's BD population PA and SB levels, and the relationship between PA, SB and mood.

6.7.2 Limitations

The response rate for this study was low (25%) despite the use of reminders and the option of paper and online questionnaires. Not all participants who returned the mailshot met the criteria of BDI/BDII or completed all four questionnaires used within this study: IPAQ, MSQ, BDI-19 and ASRM.

There was missing and/or invalid data across PA (IPAQ), SB (MSQ) and depression (BDI-19) and (hypo)mania (ASRM) questionnaires, and so not all 1031 participants were included in all aspects of analysis. This may be due to difficulties with completing and understanding the questionnaires and/or being unsure of the response, particularly in relation to estimating their PA and SB engagement. Participants have the option to add any additional information at the end of the mailshot, and some responses related to the completion of the MSQ and IPAQ questionnaires. A list of these comments is provided in Appendix R. Responses included comments that the IPAQ and MSQ were difficult to complete due to variations in routine including work and commuting, and variations in pain levels and mood. The difficulties participants experienced in completing the IPAQ and MSQ are a limitation to this study and may explain why not all participants completed the questionnaires accurately (i.e. used invalid data/missing data) or did not complete them at all.

Another limitation of this study was that items 16 and 17 of the BDI-21 were missing from participants who received a paper copy of the questionnaire mailshot, which

meant the BDI-21 had to be treated as a 19-item questionnaire (BDI-19) and these two items had to be removed from the online questionnaire mailshot also. This was done in order to keep one sample for the analyses, as statistical power would have been reduced by splitting the analyses first by 'online' and 'paper' and then with the explorations between PA, SB and mood with confounding factors, and the purpose of this study was to explore PA, SB and mood in a large sample.

Although this study had a larger sample size than study two, study two had more scope to collect information regarding factors such as medication and BMI. As this study recruited via a BDRN annual mailshot, care was taken not to overburden participants with questions, as the compilation already included ten questionnaires (including the four used in this study). The confounding factors explored in this study were taken from data already collected by BDRN at the time of initial recruitment. Employment is a factor that was not collected in study two or three which would have been helpful to know in order to explore differences between PA, SB and mood in those who were and were not employed, particularly on reflection of the variation in the MSQ time spent 'sitting at work' item.

The significance level was set at $p<0.05$ for all analyses despite multiple testing as each set of correlations were exploring relationships between similar constructs/sub-scales of the same construct and so it was expected that there would be similar outcomes and multi-collinearity, and so it is acknowledged that this increases the risk of a type one error being present in the results. The study's participant sample has more females than males, and more participants with BDI than BDII, however the numbers still allowed for meaningful comparisons between groups on self-reported PA, SB and mood symptoms (see Appendix Q).

All significant correlations within this study are small in strength, and so caution has been taken when considering what the results mean in terms of the relationship between PA, SB and mood in people living with BD so as not to overestimate the strength of the observed relationships and the implications of this in real life settings.

Furthermore, this study was cross-sectional in design and so there was no prospective data to investigate the temporality of the relationships between PA, SB and BD mood symptoms. It therefore remains unclear whether mood predicts a change in PA and/or SB, or vice versa.

6.7.3 Conclusions

This study has used self-report 7-day recall questionnaires to explore relationships between PA, SB and mood symptoms in a large UK sample of people living with BD. PA was negatively associated with depressive symptoms and positively associated with (hypo)mania symptoms. SB was associated with both depression and (hypo)mania symptoms, however this was dependant on the sitting domain. Sitting at work was negatively associated with depression, and traveling was positively associated with (hypo)mania. Sitting for leisure was positively associated with (hypo)mania, and negatively with depression. Sitting watching television was positively associated with both depression and (hypo)mania. This indicates that there is a more complex relationship between SB and mood than PA and mood.

7 Chapter Seven: Combined discussion

7.1 Introduction

This mixed-method PhD thesis has presented three studies which each explored the relationships between physical activity (PA), sedentary behaviour (SB), and mood symptoms in people living with bipolar disorder (BD) from a different perspective: that of people living with BD (study one), and what was observed from device-based measurements (study two) and subjective measurements (study three) of PA and SB in relation to self-reported mood symptoms. In study two and three, the findings from the previous study(s) were integrated to assist the interpretation of the results as the PhD progressed.

This final chapter is a synthesis of the findings of all three studies, structured in three parts: PA and SB; the relationships between PA and mood; and the relationships between SB and mood, to answer the overarching research question of this PhD: 'what are the relationships between PA, SB and mood symptoms in people living with BD?' The synthesis is followed by the original contributions to knowledge this PhD has provided, a discussion of the strengths and limitations, implications for people living with BD and future research, and the conclusions of this PhD thesis.

7.2 Physical activity & sedentary behaviour

To explore the relationships between PA, SB, and mood, this PhD provided evidence of the time people living with BD spent in PA and SB using both device-based and subjective measurements, and explored the validity of the Marshall Sitting Questionnaire (MSQ) (Marshall et al. 2010) as a self-report SB tool in people living with BD. This section therefore begins by presenting the time people living with BD

spent in PA and SB and then discusses the validity of the MSQ before discussing the relationships between time spent in PA and SB identified from this PhD.

The device-based measurement of PA produced from the ActivPAL3 (N=51) showed that participants spent on average an hour and a half a day being physically active, with 60mins of this being in MVPA. This indicates that all participants in study two met the CMO (2015, 2019) PA guidelines of 75mins vigorous/150mins moderate intensity PA (MVPA) weekly, whereas participants self-reported spending approximately just under an hour per day being physically active (60mins on average per week in MVPA) using the International Physical Activity Questionnaire (IPAQ) (N=824) in study three, and so only 40% of participants met the CMO PA guidelines. This PhD therefore shows that participant spent on average 1-1.5hrs engaged in PA per day.

The device-based measurement of SB produced from the ActivPAL3 showed that the average time participants spent in SB was approximately 10hrs per day (N=51), whereas participants self-reported using the MSQ spending approximately 9hrs per day in SB in study two (N=42) and approximately 8hrs per day in SB in study three (N=623). This PhD therefore shows a wider variation in SB engagement than PA engagement between studies, with participants spending on average 8-10hrs per day in SB. The MSQ also offered opportunity to explore the time spent in various domains of SB, and there was little variation in the domains of SB most frequently engaged with across studies two and three. Regardless of whether it was a weekday or weekend-day, sitting for work (approx. 0hrs) was the SB domain where participants spent the least amount of time sitting per day. Watching television was the most engaged with SB domain per day (approx. 3hrs), an important consideration for interventions targeting a reduction in SB engagement for this

population due to the physical (Proper et al., 2011) and mental health (Adamson et al., 2016; Hallgren et al., 2019; Zhai et al., 2015) implications of engaging in too much SB.

Although there are variations between the subjective and device-based measurements of PA and SB across the studies in this PhD, this variation is only approximately half an hour for PA, and under two hours for SB, and this is unsurprising given that different measures were used, and that there was wide variability between some participants PA and SB engagement, particularly with SB, and SB is typically less easily recalled than PA as it is usually less structured in nature (Prince et al., 2017, 2020).

In summary, across this PhD participants exhibited (using device-based measures) or self-reported (using subjective measures) slightly lower levels of SB than previous research has concluded (Janney et al., 2014; Vancampfort et al., 2017b, Vancampfort et al., 2016a); slightly higher levels of PA than some research (Janney et al., 2014; Vancampfort et al., 2018d); and slightly lower levels of PA than other research (Fellendorf et al., 2017; Melo et al., 2019). However, this PhD has used larger samples than most previous research and used more appropriate device-based measures for determining lower body movement (ActivPAL3) and established, PA and SB questionnaires with evidence of validity in BD (IPAQ and MSQ) and so have provided more reliable measurements of PA and SB in this population.

7.2.1 Validity of the Marshall Sitting Questionnaire

The MSQ time spent sitting on an average day, average weekday, average weekend-day and total week was compared to the ActivPAL3 in study two to explore the validity of the MSQ as a self-report SB tool in people living with BD.

The MSQ was found to underestimate SB by approximately 47mins per day, and so is not exempt from the limitations of self-report measures in general which are widely reported as underestimating time spent in SB (Prince et al., 2017; 2020) compared to device-based measures. Although an underestimation of 47mins per day is seemingly small, and much less than the average underestimation of an hour and a half identified by Prince et al., (2020), and the overestimation of 81mins identified in the MSQ validation in people with multiple sclerosis (Sasaki et al., 2019), this still highlights that the MSQ is not a perfect self-report SB tool.

The relationship between the ActivPAL3 and the MSQ in study two was moderate (range: r=0.283-0.344, average: r=0.3), indicating overall acceptable levels of concurrent validity between the MSQ and ActivPAL3, which was on par or better than previous research exploring the validity of SB questionnaires in the general population (see Table 2.1, page 29). Furthermore, Bland-Altman plots indicated that there were acceptable levels of agreement between the MSQ and the ActivPAL3 (as almost all points fell within the limits of agreement), and comparisons of the mean time spent sitting on the MSQ and the ActivPAL3 showed no significant differences between the measures, highlighting that the MSQ and ActivPAL3 were not statistically different from one another on their measurement of SB. However, comparisons of the relationships between device-measured SB (ActivPAL3) and self-reported sitting time (MSQ) with mood symptom severity highlighted that only the device-based measurement of SB (ActivPAL3) showed a strong positive association with (hypo)mania symptom severity ($r=0.60, p<0.05$). This is important, as it further highlights a limitation of the MSQ in the identification of relationships between SB and (hypo)mania, a finding which is discussed further in the section on ‘the relationships between SB and mood.’

Furthermore, despite the mean difference of 47mins between the MSQ and the ActivPAL3 at the group level, some participants overestimated rather than underestimated their SB, and approximately 20% of participants in study two and 40% of participants in study three were excluded from at least some analysis completely due to missing/ invalid data, and so the MSQ was not an accurate tool for all participants in this PhD. Participants who completed the MSQ as part of study three offered some insight into the completability of the MSQ by highlighting that they found it difficult due to varying time spent sitting day-to-day across the week, and so they found it a challenge to estimate their 'average' time spent sitting on a weekday or weekend day specifically (see Appendix R).

Without further exploration into the completion of the MSQ in people with BD, it is not possible to be entirely confident of either an under or over estimation (and therefore consistent bias) of the MSQ in order to improve its use, as Sasaki et al., (2019) were able to do to improve the use of the MSQ in people with multiple sclerosis. The MSQ tool should therefore be used with caution in people living with BD in future research, as further research is required to explore its validity in this population compared to other self-report measures. However, the MSQ is now the only self-report SB tool to date with evidence of agreement and validity against a device-based measure for use in this population. Future studies that use the MSQ to explore SB in this population should also acknowledge and make clear the discussed limitations, as well as any impact this may have on the results of their research.

7.2.2 Relationships between physical activity & sedentary behaviour

This PhD research found that the total time people living with BD spent in SB was negatively associated with time spent in PA (including time spent in light PA, MVPA, time spent standing, walking, and the number of steps taken). This finding was irrespective of whether a subjective or device-based measurement of PA or SB was used, or whether the relationship was explored daily or weekly, however the relationships were notably stronger in the device-based explorations of relationships between PA and SB (strong compared to small strength associations). Furthermore, this finding is in line with the relationships between PA and SB in the general population, as Mansoubi et al., (2014) found negative associations between time spent in SB with time spent in light PA and MVPA in their systematic review exploring the relationships between PA and SB engagement in the general population.

The device-based measurement in study two allowed for a more in-depth exploration into the relationship between time spent in SB and PA by exploring the number of SB bouts of various durations, and the time spent in various SB bout durations, in relation to PA. It was found that the number of SB bouts was positively associated with time spent in light PA, as was the number of SB bouts lasting 0-30mins, and time spent in SB bouts lasting 0-30mins. The number of SB bouts lasting over 30mins, and time spent in SB bouts lasting over 30mins, were found to be negatively associated with time spent in PA (as with the total time spent in SB). These findings are not surprising when you consider that a greater number of SB bouts and shorter durations of time spent in SB bouts demonstrates that sitting time is being broken up regularly (as per the CMO guidelines) and so would be positively associated with PA,

and by contrast, fewer SB bouts and more time spent in SB bouts would indicate fewer breaks in sitting time, and be negatively associated with PA in this population.

Furthermore, Rhodes, Quinlan, & Mistry (2016) found that PA is related to 'other life goals', and that the strongest associations of PA engagement was in relation to behaviour such as studying or watching television (i.e., SB engagement), rather than motivations such as 'getting healthy' and 'feeling social' which is relatable to the 'internal and external struggles' and 'determinants of volition' subthemes from the participant interviews in this PhD. These subthemes demonstrated individual reasons for doing or not doing PA, as well as reflecting the previous finding that participants spent more time sitting watching television than in any other SB domain and spent more time in SB than PA across all device-based and subjective measurements in this PhD. These combined findings are important as they have provided evidence of the PA and SB engagement of people living with BD, the negative relationship between time spent in PA and SB in people living with BD, and insight into why less time in PA is associated with more time in SB in people living with BD.

7.3 Relationships between physical activity & mood

This PhD identified several important findings relating to the relationships between PA engagement and BD mood symptoms which are discussed in this section.

There were a greater number of significant associations in this PhD identified from daily (device-based) measures of PA and mood (N=17) than associations between weekly measured PA (device-based measurement, N=3 or subjectively, N=10) and the total scores for depression and (hypo)mania symptom severity. This suggests that relationships between PA and mood symptoms are more easily identified using

daily measures of PA and mood, rather than using a weekly measure of PA and mood, particularly in studies with a smaller participant sample. This may be because weekly measures represent a whole 7-day period during which time a significant change to PA engagement or mood symptom severity may have occurred, making it difficult to identify significant associations between weekly PA and specific mood symptoms.

Both device-based and subjective measurements of PA and self-reported depressive symptoms in this PhD showed negative relationships whereby lower levels of MVPA were associated with a higher incidence of daily 'sadness' ratings ($r=-0.24, p<0.05$), and weekly depression symptom severity (QIDS: $r=-0.40$ to -0.56, BDI-19: $r=-0.08$ to -0.17). It was not clear from these analyses whether low mood was the reason for not engaging in PA, or whether not engaging in PA had led to low mood. However, it was the view of several participants interviewed that if they were 'too low in mood' or 'too deep into depression', that PA was not going to be beneficial. Participants also alluded to possible explanations for this in the interviews, commenting on fatigue, a lack of motivation, and a perceived lack of ability to engage with activities, despite also commenting that PA was helpful for mood regulation and something that potentially prevented depressive episodes. This evidences PA being viewed as a useful mood maintenance tool, and as a preventative treatment for low mood, but not necessarily as being an effective *treatment* for low mood. Wright et al., (2012) support this, as they identified that exercise was viewed as being ineffective as a treatment tool if someone was already too high or too low in their mood, an important consideration for people living with BD.

This PhD identified positive associations of higher levels of PA engagement and (hypo)mania symptoms, including associations between daily time spent in MVPA

and daily ratings of *'energy'* (r=0.21) and *'energetic'* (r=0.21) (both only in females), and associations between weekly time spent in MVPA, walking, and total PA with weekly (hypo)mania symptoms, including: increased *'activity'* (r=0.10-0.18); *'confidence'* (r=0.09-0.10); *'happiness'* (r=0.10) and overall (hypo)mania symptom severity (r=0.16-0.11). This supports more recent findings from research exploring PA specifically in (hypo)manic patients which also identified positive associations of (hypo)mania and higher levels of PA engagement (Krane-Gartiser et al., 2017; Krane-Gartiser et al., 2018a; Scott et al., 2017). The interviewed participants in this PhD offered a novel insight into these findings, as participants stated they disengaged with their usual PA behaviours when they felt high or low in mood, and specifically disengagement with structured routine exercise, and this was considered a feature of a (hypo)manic mood episode. Despite PA being perceived to be generally increased by participants when experiencing (hypo)mania, this was described as being less structured or organised, driven by a perceived physical *need* to move, rather than for a specific purpose (such as keeping fit or for mood maintenance). This is an important finding which helps to explain the associations between PA engagement and (hypo)mania symptoms in this population. Vancampfort et al., (2017b)'s systematic review also highlighted that people living with BD can engage in high levels of PA, (particularly MVPA), and particularly when higher in mood, and this PhD has evidenced that people living with BD engaged in more vigorous intensity PA when also experiencing (hypo)mania symptoms. The participant interviews also offered insight into the type of PA that was perceived as unhelpful when high in mood, and it was identified that vigorous intensity activities, or activities that produced feelings of elation and/or achievement for that participant made them wary of triggering a high mood episode or making an existing episode

worse. It can be concluded from this PhD thesis that high intensity, vigorous PA may be unhelpful for people living with BD when experiencing (hypo)mania, given the significant associations between MVPA and (hypo)mania, and the participant perceptions of vigorous intensity PA being unhelpful during (hypo)mania.

Furthermore, study two identified an important finding whereby males engaged in more time in device-measured daily MVPA than females, and self-reported higher daily ratings of 'elation' and 'energy' than females. Significant, positive associations were found between time spent in MVPA and ratings of 'elation' and 'energy,' however, on further exploration of the above differences between males and females, it was found that these associations were only significant in females (both r=0.21), despite females engaging in less MVPA, and having lower ratings of 'elation' and 'energy than males. In the participant interviews it was highlighted that females described a 'fear of (hypo)mania' and actively avoided engaging in higher intensity PA (or exercises) when they believed it may 'trigger' or worsen (hypo)mania. These combined findings therefore suggest that the female participants in these studies experienced stronger relationships between PA, specifically MVPA, and (hypo)mania symptom severity.

As part of the exploration between PA and mood symptoms, additional factors that may be confounding the relationship were explored. It was identified that BMI, gender and the length of BD illness (yrs) are confounding factors in the relationship between PA (specifically time spent in MVPA and light PA and time spent walking or standing), and mood (specifically feeling 'energetic' or 'elated') in people living with BD. Given the relatively small sample size in study two used to identify potential factors confounding any relationship between PA, SB and mood symptoms (N=51), study three provided a further opportunity to explore certain factors (gender, physical

health comorbidities, age and psychiatric history) in a larger sample (N=1031), and it was identified that there were no significant differences between males and females other than depression severity in this larger sample, with females scoring higher than males on the BDI-19. There were however significant differences between the PA engagement and severity of mood symptoms between those with BDI and BDII (with those with BDII engaging in more PA however also experiencing high levels of depressive symptoms), and the presence or not of hypertension (with those without a history of hypertension engaging in more PA and experiencing lower levels of depressive symptoms) (see Appendix Q for analyses). This is in contrast to study two which found no significant differences between BD sub-type or having a history of hypertension on PA engagement and mood. However, the subjective exploration (study three) identified that none of the explored factors confounded any of the relationships between PA and mood in people living with BD. This may be due to the use of subjective measurements in study three, as the previous section highlighted that the device-based measurements of PA and SB showed stronger associations with mood than the subjective measures, and so there is a risk of PA and mood associations being underestimated/ missed when using subjective measurements of PA (as in study three).

In summary, both device-based and subjective measurements of PA showed positive associations with (hypo)mania symptoms and negative associations with depressive symptoms, but stronger associations were found between device-measured PA and self-reported mood symptoms than subjectively measured PA. Given these identified associations and the wide variation between participants' PA engagement highlighted previously, this variation could be at least in part due to mood state, and the participant interviews have further supported this by highlighting

how increases and decreases to PA were also perceived to be related to changes to mood.

7.4 Relationships between sedentary behaviour & mood

As well as relationships between PA and mood, this PhD has also provided a novel insight into the relationships between SB and mood in people living with BD, particularly in relation to SB and (hypo)mania symptoms. However, overall there were fewer associations between SB and mood symptoms than PA and mood symptoms identified in this PhD.

In study two there were positive associations between daily time spent in SB bouts lasting over 120mins and daily ratings of 'sadness' ($r=0.12, p<0.001$); and between weekly total time spent in SB and depression symptoms *'time taken to fall asleep'* ($r=0.50, p<0.001$) and *'feeling slowed down'* ($r=0.35, p<0.001$) which is in line with previous research suggesting a positive relationship between SB and depression (Teychenne et al., 2010; Vancampfort et al., 2018b; Zhai et al., 2015). However, there was also a strong positive association between device-measured weekly time spent in SB and (hypo)mania symptom severity in those using anti-depressants ($r=0.60, p<0.05$). This is despite low variation in weekly individual (hypo)mania mood symptoms and the total scores for symptom severity as well as there being a smaller sample size in the weekly explorations of device-measured SB and mood symptoms compared to subjectively measured SB and mood symptoms (study three). A likely explanation for this finding, is that the use of anti-depressants is a potential trigger for (hypo)mania for people living with BD (Phillips & Kupfer, 2013) which is supported by the participant interviews through the subtheme of 'medication: a gatekeeper for activity,' which highlighted the difficulty of not only balancing PA, SB

and mood, but balancing this alongside medication, with one participant commenting that if medication was not balanced, they could end up being *'too high or too low because of it'* and that this was perceived to be related to either *'doing too much activity'* (being *'too high'*) or being *'too sluggish'* or *'not motivated'* (being *'too low'*). It is also possible that the positive associations observed between SB and (hypo)mania could be due to more participants being in mixed state (13%) i.e., reporting both (hypo)manic *and* depressive symptoms than (hypo)mania alone (6%); and/or due to reduced sleep, given the positive association between *'time taken to fall asleep'* and total time spent sitting (APA, 2013), which could therefore result in more time spent awake, but not asleep, further explaining this association. The participant interviews provided support for this theory, as participants referred to spending less time in bed and getting up in the night and needing less sleep when experiencing (hypo)mania. Furthermore, this PhD has identified that not only is the use of anti-depressants positively associated with (hypo)mania, but also time spent in SB, which has been identified in previous research as a risk factor for physical health conditions such as cardiovascular disease and type 2 diabetes (Proper et al., 2011). Time spent in SB has also been associated with poor mental health relating to depression (Zhai et al., 2015) and anxiety (Teychenne et al., 2015) in previous research, and this PhD has now identified through participant interviews that medication is perceived to be a factor related to PA, SB and mood, and then evidenced that time spent in SB was strongly associated with (hypo)mania in people with BD who were using anti-depressants.

Another novel finding of this PhD research were the associations between time spent in different SB domains with mood, which helps to explain the previous finding that total time spent in SB was positively associated with both (hypo)mania symptoms

and total symptom severity as well as some depression symptoms. Sitting using a screen was positively associated with depression symptom severity, however sitting for work or for leisure was negatively associated with depression symptom severity. Sitting for leisure and for travel were positively associated with (hypo)mania symptom severity, and sitting watching television was positively associated with both depression and (hypo)mania symptom severity. This highlights the importance of exploring SB and mood specifically in this population, as previous research into SB and mental health has only found links between SB and depression (Zhai et al., 2015) and anxiety (Teychenne et al., 2015), and not explored a possible association between SB and (hypo)mania. This has led to conclusions in previous literature that reducing SB engagement will be helpful for mental as well as physical health (Fraser, Brown, Whiteford, & Burton, 2014; Hallgren et al., 2019; Teychenne et al., 2010; 2020; Zhai et al., 2015) without considering whether SB is actually always unhelpful for mental health. The current PhD has shown the SB and mood relationship to be much more complex in people living with BD, with participant interviews highlighting that SB can actually be helpful for relaxation, routine, and mood stability, and for counteracting (hypo)mania symptoms by enforcing stillness and calmness, as well as also reducing the time spent in activity that was perceived as being unhelpful and maintaining the (hypo)manic mood state, i.e. high intensity PA. The complex relationship of SB and mood can be explained further through the finding that SB domains including sitting for leisure or for travel were positively associated with (hypo)mania symptoms. Travel was identified as a potential high mood trigger in the participant interviews, with participants providing examples of when travelling had preceded an experience of (hypo)mania. Furthermore, sitting for leisure encapsulates social activities and engaging with projects/hobbies which

interviewed participants reported engaging in during (hypo)mania, and an increase in goal-orientated activities is a diagnostic criteria for (hypo)mania (APA, 2013). This likely explains the positive association of sitting for leisure with (hypo)mania, particularly as the exploration of device-measured SB and (hypo)mania also identified positive associations of *'talking more often than usual'* (a social activity) and time spent in SB.

Sitting watching television was positively associated with depressive and (hypo)manic symptoms in the subjective exploration of this PhD, and interviewed participants said they were more likely to sit in front of the television all day if they felt depressed, although they may not necessarily be engaged in the television content. Recent research has identified that the risk of depression (in the general population) can be reduced by up to 5% by replacing 30mins of 'passive' SB per day (such as watching television) with a mentally active SB (such as a puzzle) (Hallgren et al., 2019). This risk is reduced further if 30mins of SB was replaced by PA (13-19%) (Hallgren et al., 2019). The recommendation of replacing passive with active SB may be helpful for people with BD, as participants voiced in the participant interviews that knowing PA may help their low mood was not enough motivation to then engage in PA. Therefore replacing 'passive' with 'active' SB may be more achievable and realistic for severely depressed patients. Given the discussed associations between SB domains of 'leisure' and 'travel' with (hypo)mania, this would not be a helpful recommendation for participants experiencing (hypo)mania and may actually worsen symptoms as increased 'activity' is in the diagnostic criteria for a (hypo)manic episode (APA, 2013), and sitting for the purpose of travel or leisure are already likely to be more mentally 'active' than 'passive' behaviours. Participants identified in the participant interviews that watching television or going to the cinema can help

enforce stillness when experiencing (hypo)mania and feel helpful, again further highlighting the overarching theme of 'trying to maintain balance,' rather than there being a one size fits all level of 'healthy' SB engagement for people living with BD. It is unknown however whether the positive associations of (hypo)mania and SB identified in this PhD are due to attempts to maintain balance after identifying high mood, or are acts which may worsen the symptoms. For example, sitting watching television may be helpful for (hypo)mania if it is a calming programme, or worsen symptoms if the television viewing is stimulating, for example an action film, which was the view of one interviewed participant who said that seeing an action film when (hypo)manic would be 'counterproductive.' Hallgren et al., (2019) also report that the impact of changing PA (increasing) or SB (reducing) levels on reducing the risk of depression is small (5-19%) and conclude that there are likely other environmental factors affecting individual changes in mood and SB engagement, which also reflects the conclusions of all three studies in this PhD.

In summary, both the device-measured and subjective measurements of SB in this PhD were identified as having negative and positive associations with (hypo)mania symptom severity and depression symptom severity depending on the nature of the SB being engaged with, indicating the relationship between SB and mood to be complex in people living with BD.

7.5 Original contributions to knowledge

This PhD offers the first exploration of experiences of PA, SB *and* mood from the perspectives of people living with BD, and has offered the first insight into perceptions of a relationship between SB and mood symptoms in this population. This PhD research was also the first to explore daily and weekly PA and SB using the most appropriate activity monitor for calculating both PA *and* SB (the ActivPAL3), alongside daily and weekly self-reported mood symptoms; and subjectively explored self-reported PA and SB alongside mood symptoms in people living with BD using established PA (IPAQ) and SB (MSQ) questionnaires in the largest sample known to date.

This PhD has therefore provided more accurate evidence of the PA and SB levels of people living with BD due to the use of these appropriate tools in larger samples than those used in previous research. Furthermore, study two includes the first attempt to explore the validity of an SB questionnaire (the MSQ) for use in BD and highlights the degree to which SB may be underestimated in this population (47mins), whilst acknowledging that there may also be difficulties with completing the MSQ completely and accurately in this population. This PhD provides the first known evidence supporting the use of any such tool in this population (albeit to be used with caution), and indeed the first to use this tool to explore relationships between SB domains and mood symptoms. This exploration offered a valuable insight into relationships between domains of SB and mood symptoms, demonstrating that SB is not only associated with low mood in this population.

This PhD has offered a unique insight specifically into PA and SB in people living with BD in the UK, and the relationships between PA, SB and the depressive and (hypo)manic mood symptoms characteristic of this population.

7.6 Strengths

In addition to providing original contributions to knowledge, there are other notable strengths of this PhD. These include a thorough review of the most suitable device-based and subjective measurement tools of PA and SB for use in people with BD (chapter two); recruiting from the largest research network of people living with BD in the world (BDRN); and the mixed methods approach which allowed for the integration of participant interviews to help provide insight into the 'real-life' presentation of relationships between PA, SB and mood for people living with BD.

This PhD has explored both daily and weekly relationships of PA, SB and mood symptoms using a device-based measurements of PA and SB: the ActivPAL3, and compared the relationships between weekly device-measured PA, SB and mood symptoms with subjectively weekly measured PA, SB and mood symptoms, as well as provided evidence of the validity of the MSQ as a self-report SB tool for use in this population. Furthermore, this PhD has the largest participant samples of people living with BD who have completed the IPAQ and the MSQ, or worn an ActivPAL3 to date.

Although this PhD had more depressed participants engage in study's two and three (according to the QIDS and BDI-19), participants who were experiencing more significant mood symptoms were not necessarily excluded for not being 'euthymic,' and so this PhD included participants with (hypo)mania (according to the ASRM) and/or mixed state symptoms, which has enabled a more representative exploration

of PA, SB and mood symptoms in BD (and in a natural setting) than that of previous research which largely only included depressed or euthymic patients, and from inpatient psychiatric settings.

This PhD also considered other demographic, clinical and environmental factors identified from previous research as potentially being associated with PA and/or SB (Vancampfort et al., 2013) to explore whether these were confounding factors in the relationship between PA, SB and BD.

7.7 Limitations

The majority of participants across all three studies of this PhD were female, over 50 years of age, reported their ethnicity as 'UK white', and had a best-estimate main lifetime DSM-IV diagnosis of BDI. This is not uncharacteristic of the BDRN participant sample, nor of previous research (other than ethnicity). For example: Kilbourne et al., (2007) recruited 2032 participants with BD, and 67% of these were over 50 (mean= 55.18 (±12.54)); Melo et al., (2019) had a similar mean age of 42.4 (±12.7) in their study which included 80 participants, and also had more participants who were female (61.3%) and with a diagnosis of BDI (86.3%) as with the current PhD. Furthermore, this PhD is now one of only two (Wright et al., 2012) known explorations of PA and mood specifically in people living with BD in the UK population. However, it is acknowledged that this makes the findings of this PhD somewhat limited in terms of wider generalisability, and if this PhD was to be replicated it would be beneficial to attempt more targeted recruitment of males and participants with BDII, and from other age groups and ethnicities.

Previous research has often used the terms 'exercise' and 'PA' synonymously (Bauer et al., 2016; Cairney et al., 2009; Fraser, et al., 2015; Hoffmann et al., 2015)

and the terms ‘SB’ and ‘inactivity’ synonymously (Branco et al., 2014; Fraser et al., 2014; Tremblay et al., 2017) despite being different constructs which has caused issues when interpreting and comparing PA and SB levels across research. During the participant interviews, participants were asked to talk about experiences of ‘exercise’ separately to ‘day-to-day activity/movement’ to separate these constructs and understand experiences of exercise and mood compared with everyday PA and mood as previous published research had largely focused on exercise. However, participants still used ‘exercise’ and ‘PA’ interchangeably, referring to everyday PA as their ‘exercise,’ at times, possibly because that was the only PA they engaged with at the time and so were perhaps more likely to view these behaviours as exercise. The participant interviews did show that participants were aware of how different behaviours related to their mood, for example which provided structure or routine, which were helpful (balanced) or unhelpful (unbalanced) at different times. However, using the appropriate terminology is important for researchers to be able to interpret and make sense of experiences through a shared understanding of the concept being discussed, and for the purpose of agreeing definitions and distinguishing between PA and exercise. This was a particular challenge of this PhD, as the researcher often had to interpret from the interviews the PA that was being engaged with, despite asking about experiences of exercise first to distinguish this from day-to-day PA. On reflection, it may have been helpful to have spent time at the start of the interview discussing the definitions of these constructs, including conversations around intensity, rather than simply saying for example, ‘‘by PA I mean day-to-day activities that require physical movement.’’ This itself is still an important finding, as confusion over what constitutes ‘exercise’ and PA, may make it difficult for participants to understand and engage with PA recommendations, and

should be a consideration for interventional studies aiming to increase PA in this population, i.e. to consider participants' understanding of 'exercise' and PA more generally. Furthermore, it is also unclear how participants would have approached the IPAQ self-report questionnaire used in this PhD in terms of viewing PA as exercise as the IPAQ refers to vigorous and moderate intensity PA rather than asking about types of exercise engaged with, so it is unclear whether any high intensity or moderate intensity PA engaged with was through employment, travelling, or for the purpose of keeping fit and healthy.

The mixed results concerning the exploration of environmental, demographic and psychiatric history as confounding factors in the relationships between PA, SB and mood symptoms in studies two and three of this PhD should be treated with caution due to no adjustments being made to account for multiple testing, and the absence of information on physical health comorbidities, BMI, and medication for all participants who participated in either study two (device-measured) or three (subjective) as this information was taken from the self-reports of participants, and not all participants had chosen to provide this information. However, these findings are important for evidencing the complexity of the relationship between PA, SB, and mood symptoms, and that other factors may be relevant to the relationship between these variables and highlights the contribution of individual differences, as well as the associations between device-measured PA, SB and mood being stronger than associations between subjectively measured PA, SB and mood.

This PhD did not explore temporal relationships between PA, SB and mood in order to determine whether a change in PA and/or SB precedes or follows a change in mood. Variations in mood can be difficult to identify within cross-sectional research using a one-off measurement of mood, particularly (hypo)mania, as episodes are

less frequent and do not usually last as long as depressive episodes (APA, 2013). This has been a limitation with the current PhD, and of previous research into PA and SB and the expression of (hypo)manic symptoms in-particular (Branco et al., 2014; Cairney et al., 2009; Elmslie et al., 2001; Helgadóttir et al., 2015; Stubbs et al., 2018; Vancampfort et al., 2016a; Vancampfort et al., 2015d). Whilst study two of this PhD gathered daily PA, SB, and mood data over a 7-day period, the sample size was not large enough and there was not enough mood variation in the data to explore these relationships bidirectionally and examine temporal relationships.

There are a number of variables which were not collected within this study which may have provided further knowledge, such as any current physical injury, physical disability, and employment. The employment status and type of employment of participants was not known. Employment adds more structure to the day, and therefore may have aided recall ability on the IAPQ and MSQ questionnaires (Prince et al., 2008; 2017). Furthermore, a proportion of the participants in each study were above the UK retirement age (65yrs): study one=33%, study two=14% and study three=28% which may have impacted on their PA and SB engagement, and ability to recall less structured day-to-day activities due to not having the structure of being employed. Employment is also a factor likely to limit the ability for participants to make changes to their PA and SB levels and is unique to individuals, for example someone with a very physically active job role may not be able to reduce their engagement with high intensity PA to see if perhaps this helps prevent a full (hypo)manic episode, and someone working at a desk may struggle to reduce their SB to see if this helps prevent or manage a depressive episode.

A further limitation to this PhD is the amount of missing data from the self-report PA and SB tools, which meant that not all 51 participants from study two were included in the analysis attempting to validate the MSQ against the ActivPAL3 (weekday analysis=44, weekend-day analysis=42, total week=37). Only 60% of participants had full MSQ data in study three, and only 80% had full IPAQ data. The MSQ has five domains requiring a response for both weekday and weekend-day, and so has ten opportunities for missing/ invalid data to be provided, whereas the IPAQ only had six opportunities (excluding the sitting question) for missing/invalid data which may explain why there was a greater amount of missing data from the MSQ. One possible explanation why the PA and SB questionnaires provided more missing/invalid data compared to the mood questionnaires, is that the mood questionnaires only require participants to tick a box from a pre-defined list of responses, whereas both the MSQ and the IPAQ require participants to consider and write their own response in the correct format (e.g., HH:MM). A further explanation, given the identified associations between PA, SB, and mood in this population, is that behaviours may be difficult to estimate in terms of an 'average day' using a 7-day recall tool as this may vary if a participant has experienced changing PA and SB levels during this time, which was anecdotally provided by participants (see Appendix R).

7.8 Implications for people living with bipolar disorder

The participant interviews highlighted the potential benefit of having personalised exercise support to incorporate individual differences, and it was suggested this should be someone who is aware of the mood symptoms people living with BD can experience, and how this may impact on their perceived ability (mentally and physically) to engage in PA, taking into consideration volition, motivation, mood triggers, and the effects of medication (e.g., fatigue, lack of energy). Although previous research has mostly tried to understand PA and SB more widely at a group level to make broad recommendations for the treatment and management of BD in this population, it may be of more help to people living with BD to consider monitoring their PA, SB, mood, and other factors to enable them to make the most supported choices for balancing PA and SB to improve the self-management of mood symptoms. Krane-Gartiser et al., (2018b)'s longitudinal case-series study included three BD participants and highlighted variability between participants across different mood states, but similarities in their activity within mood states, and concluded that changes in activity, particularly irregularities in activity, could help to identify and distinguish BD mood states, however a greater number of case study examples are required to explore this further and identify factors which may be relevant to manage alongside PA in relation to mood.

Although previous research has acknowledged that increasing PA may be beneficial for mental health in the general population (Conti & Ramos, 2018; Pickett et al., 2012; Rebar et al., 2015; Schuch et al., 2019), findings of this PhD (the participant interviews, and positive associations of (hypo)manic symptoms and MVPA and vigorous intensity PA engagement) suggest that increasing PA does not necessarily

always improve mental health in this population, and any benefit obtained from increasing PA is at least in part related to the severity of mood symptoms being experienced by the participant. Whether this is directly due to the PA increase, or other related factors such as any social engagement, or other environmental factors requires further exploration. However, it is a recommendation from this PhD that people living with BD consider the intensity and type of PA they engage in when experiencing (hypo)mania, and whether they feel the impact of engaging in the PA behaviour will be helpful or unhelpful for maintaining a sense of balance.

This PhD has shown the complex relationships between PA, SB and mood. Time spent in SB was positively and negatively associated with weekly (hypo)mania symptom severity, and time spent in MVPA was negatively associated with daily irritability and sadness, but positively with energy and elation. Irritability can be a feature of both (hypo)mania and depression, as well as anxiety, however there were no statistically significant associations between anxiety and PA or SB found in this PhD. Participants talked in the interviews of either feeling a ‘need to move’ when anxious or irritable or ‘not wanting to do anything’ highlighting that anxiety and irritability may contribute both to PA (particularly MVPA) and SB for different people. The current PA guidelines of 75-150mins of MVPA may not be suitable for people living with BD, as meeting the 75-150mins may not always bring about positive mental health benefits if the PA is related to (hypo)mania symptoms such as irritability. Further, meeting these guidelines may not even be achievable for some people living with BD who are experiencing irritability in relation to depression. It may be more helpful for people living with BD to work with health professionals to create their own personalised, flexible PA goals which are achievable and help them to

recognise when it may be helpful to reduce PA (specifically MVPA) engagement, not only focusing on meeting MVPA guidelines.

Given that this PhD has highlighted different statistically significant relationships of PA and mood (between males and females, those using and not using anti-depressant use, across BMI categories, and across varying lengths of BD illness [yrs]); as well as other differences between PA, SB and mood engagement between individuals (see Appendices R & Q); and also highlighted a perceived positive impact of personalised exercise support, (i.e. someone who understands BD), it is also a recommendation from this PhD that individual differences and needs be taken into account by those recommending increasing PA or reducing SB engagement in order to maintain balance, rather than a 'one size fits all' recommendation of increasing PA and reducing SB to improve mental and physical health which may not be achievable or realistic for everyone living with BD.

7.9 Implications for future research

This PhD has identified a need for future research to explore temporal relationships between PA, SB, and mood in BD. A longitudinal monitoring of PA, SB (preferably using device-based measurements) and mood is therefore required to identify and track changes which could ultimately determine whether a change in PA and/or SB precedes a change in mood symptom severity, or whether a change in mood symptom severity precedes a change in PA and/or SB. Jebb et al., (2015), and McCleary et al., (1980) recommend collecting data from 50 independent time points for time-series analysis when exploring psychological phenomena, with a minimum of 20 time points to ensure this is long enough to capture and establish the relationship of interest (in this case, PA, SB, and mood). Given that seasonality is

also an issue for time-series analysis, monitoring PA, SB, and mood symptoms (alongside other environmental factors or significant events, e.g., bereavement or physical injury) in a large sample of participants during the same time period will help the identification and consideration of mood changes linked to seasonal changes which can in themselves be triggers for mood episodes (APA, 2013). A study like this would also help to identify whether PA and/or SB really are 'triggers' or early warning signs for mood changes as considered in study one of this PhD, or whether changes to PA and/or SB are a consequence of mood changes. This is knowledge that would be immensely valuable to clinicians and people living with BD to prevent and manage the onset of mood episodes.

Given this PhD has identified associations between PA, SB and mood symptoms in people living with BD, exploring PA and SB levels across mood episodes (e.g. comparing participants PA and SB levels when they are depressed, (hypo)manic, euthymic and in mixed-state may offer an alternative perspective on the relationships between PA, SB and mood in people living with BD. This could be done in line with the above suggestion of monitoring PA, SB, and mood temporally, and identifying mood episodes to explore PA and SB in more depth in relation to these episodes, particularly as the severity of the episode may vary between those with BDI and BDII, and so may demonstrate differing relationships with PA and SB between episodes. This PhD thesis has demonstrated across three studies that the variation of PA and SB levels between individuals may be related to mood, as well as other factors (volition, motivation, mood triggers, medication, or other environmental factors) and so this would be a logical next step for future research.

Furthermore, future research should continue to explore individual differences and identify potential clinical, demographic and environmental factors which may be relevant to the relationships between PA, SB and mood symptoms in people living with BD to provide evidence-based recommendations for balancing PA and SB engagement alongside mood.

Previous research identifying people living with BD as being less active and more sedentary than the general population (Elmslie et al., 2001; Janney et al., 2014; Shah et al., 2007; Strohle et al., 2007) had predominantly explored depressed BD patients, or patients who were considered to not be experiencing any severe mood symptoms, but could be experiencing mild/moderate depressive symptoms. Given the current PhD's findings that higher levels of depression were associated with lower levels of PA, and higher levels of SB, it is important to consider if whether the findings of previous research should consider reframing this conclusion as, 'people living with BD are less active and more sedentary when experiencing depression,' particularly as time spent in PA was positively associated with (hypo)mania. Given that (hypo)manic episodes are less frequent and typically shorter than depressive episodes (APA, 2013; Phillips & Kupfer, 2013), it is unsurprising that at a group level, people living with BD may appear less active and more sedentary, however it is not acknowledged enough in previous literature that this is an episodic illness, of which PA and SB changes are but one aspect of behaviour changes that may occur alongside a change in mood symptoms, or a full mood episode. It is therefore not appropriate to assume that the characteristics of all SMIs are similar enough to include these groups as one sample, and doing so could lead to conclusions that are not reflective of the changing PA and SB levels of people living with BD when experiencing different mood episodes, particularly given that people with BD were

highlighted as being underrepresented in previous mixed-sampled research (Chwastiak et al., 2011; Leyland et al., 2018; Pearsall et al., 2014; Zechner & Gill, 2016). Research exploring PA and SB in people living with an SMI should therefore continue to explore people living with BD separately from other diagnoses, unless for the purpose of comparing groups.

A potential area for future research to explore further is the use of illness metaphors in BD. Many participants interviewed in study one of this PhD made use of illness metaphors to describe what it is like to live with BD, such as the 'self-feeding monster' metaphor. The use of metaphors helped the researcher to understand participant perceptions of BD and how living with BD impacted on their PA and SB engagement. Although the metaphors used were all negative depictions of BD, they provided participants with an opportunity to express their struggle when attempting to maintain balance between PA, SB and mood. Illness metaphors helped to describe to the researcher the perceived lack of control participants had during full episodes of depression or (hypo)mania. The metaphors highlighted how this made regular PA engagement challenging, as there was always a perceived risk of being 'too low' to engage in PA, or engaging in too much PA and being 'too high' as a result. Further research into the use of illness metaphors could help to break down stigma around mental health more generally, as well as specifically in BD, as they offer a unique insight and may help people living with BD to feel their struggles are more understood and accepted as a result. The use of illness metaphors therefore warrants further exploration.

Future research should also continue to determine the validity of PA and SB self-report tools to see if there is a more suitable PA tool than the IPAQ, or a more suitable SB tool than the MSQ for use in the BD population with lower

underestimations than was identified in study two (47mins). If the collective validity of PA and SB across the board of self-report tools is low in this population, it may be worth developing PA and SB self-report tools specifically for use in people with BD which can take into account the association between PA, SB and mood symptoms as identified in this research.

7.10 Conclusions

This PhD presented an exploration of PA, SB, and mood symptoms in people living with BD with a focus on exploring the relationships between these variables using the most appropriate PA and SB measurement tools available at the time for use in this population. People living with BD spent approximately 1-1.5hrs per day in PA, and 8-10hrs per day in SB, and less time spent in PA was associated with more time spent in SB. However, the MSQ tool used to contribute to these estimates may underestimate SB in people living with BD by approximately 47mins, and so this tool should be used with caution in this population in the absence of a fully validated tool.

Across the three studies of this PhD there were associations made between PA, SB, and mood symptoms: with higher levels of PA being associated with high mood; and lower levels of PA being associated with low mood; and more time spent in SB being associated with both high and low mood, depending on the type of SB engaged with: sitting watching television was positively associated with both depressive and (hypo)manic symptoms; sitting for leisure was positively associated with (hypo)mania and negatively with depression; sitting for travel was positively associated with (hypo)mania, whereas sitting using a screen was positively associated with depression, and sitting for work was negatively associated with depression. The overarching theme of ‘trying to maintain balance’ from participant interviews

describes the impact of these associations through a struggle to not be too physically active when high in mood, but avoid not being physically active enough when low in mood. It also describes the struggle to not be too sedentary when low in mood, but to also recognise when being sedentary feels helpful during high mood, and to find that personal, optimal level at which PA, SB and mood all feel balanced. Furthermore, gender, BMI, the use of anti-depressant medication and the length of BD illness (yrs) were found to be confounding factors in the relationships between PA, SB and mood.

This PhD has evidenced that people living with BD experience complex relationships between PA, SB and mood that are difficult to balance. The PA sector should consider a more personalised, flexible approach to future PA guidelines in relation to mental health. These guidelines should not only acknowledge that PA (particularly MVPA) may not always be helpful for people living with BD (particularly when experiencing (hypo)mania), but also promote more realistic, achievable PA goals for people experiencing depression. Furthermore, those working with people living with SMIs (including clinicians and mental health support workers) should consider utilising the findings of this PhD to support people living with BD to reflect on their mood and PA and SB engagement and make appropriate changes where necessary to create a better balance.

Future research should continue to explore PA, SB and mood in people living with BD independently of other mental health populations in respect of their PA and SB engagement due to the presence of (hypo)manic symptoms typically uncharacteristic of other diagnoses, which have been demonstrated as being associated with their PA and SB engagement in this PhD. Intervention research could consider the results of this PhD when recommending an increase in PA or decrease in SB for the

treatment and management of mood symptoms in this population, given the potential for changes in PA and/or SB being associated with mood symptom severity. Future research should therefore explore temporal relationships and possible bidirectionality between changes in PA, SB and mood symptoms in people living with BD, to determine whether a change in PA or SB is a trigger or early warning sign of a mood episode.

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9 Appendices

Appendix A: International Physical Activity Questionnaire

Appendix B: Marshall Sitting Questionnaire

Appendix C: Altman Self-Rating Mania Scale

Appendix D: Quick Inventory of Depressive Symptoms

Appendix E: Beck Depression Inventory

Appendix F: Search criteria & selection process for eligible BDRN participants (studies one & two)

Appendix G: Chapter four (study one) interview recruitment email & interview confirmation email

Appendix H: Chapter four (study one) examples of colour coding transcripts

Appendix I: Chapter four (study one) supplementary information on early theming

Appendix J: Chapter five (study two) recruitment email, information leaflet & confirmation email

Appendix K: Chapter five (study two) ActivPAL3 instructions & guidance

Appendix L: Chapter five (study two) study pack (first three days)

Appendix M: Chapter five (study two) postal delivery postal letter

Appendix N: Chapter five (study two) participant thank you letter

Appendix O: Chapter five (study two) supplementary analysis between two methods for removal of sleep time from raw ActivPAL3 data

Appendix P: Chapter five (study two) additional analyses – identifying confounding factors

Appendix Q: Chapter six (study three) additional analyses – identifying confounding factors

Appendix R: Chapter six (study three) additional comments from participants regarding the International Physical Activity Questionnaire & the Marshall Sitting Questionnaire

Appendix S: Researcher's background, motivations & reflections

9.1 Appendix A: International Physical Activity Questionnaire

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your housework and gardening, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ **days per week**

☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

9.2 Appendix B: Marshall Sitting Questionnaire

The Marshall Sitting Questionnaire

For the past 7 days, please estimate how much time (in hours and minutes) you spent on average **SITTING** each day in the following situations: (please write your answer, or N/A if not applicable).

Please provide a **DAILY** average for each situation– not the weekly total.

	On average, on a WEEK DAY		On average, on a WEEKEND DAY	
	Hours	Minutes	Hours	Minutes
While traveling to and from places				
While at work				
While watching television				
While using a screen, NOT including while watching television, (e.g., using a computer/ laptop/ tablet/ games console/ smartphone etc.)				
In your leisure time, NOT including television or other screen time as listed above (e.g., visiting friends, movies, dining out, etc.)				

9.3 Appendix C: Altman Self-Rating Mania Scale

Altman Self-rating Mania Scale (ASRM)

*Please circle the response (0-4) to **each item** that best describes you for the **past seven days**.*

Item	0	1	2	3	4
1: Happiness	I do not feel happier or more cheerful than usual 0	I occasionally feel happier or more cheerful than usual 1	I often feel happier or more cheerful than usual 2	I feel happier or more cheerful than usual most of the time 3	I feel happier or more cheerful than usual all of the time 4
2: Confidence	I do not feel more self-confident than usual 0	I occasionally feel more self-confident than usual 1	I often feel more self-confident than usual 2	I feel more self-confident than usual most of the time 3	I feel extremely self-confident all of the time 4
3: Sleep	I do not need less sleep than usual 0	I occasionally need less sleep than usual 1	I often need less sleep than usual 2	I frequently need less sleep than usual 3	I can go all day and all night without any sleep and still not feel tired 4
4: Talking	I do not talk more than usual 0	I occasionally talk more than usual 1	I often talk more than usual 2	I frequently talk more than usual 3	I talk constantly and cannot be interrupted 4
5: Activity	I have not been more active (either socially, sexually, at work, home or school) than usual 0	I have occasionally been more active than usual 1	I have often been more active than usual 2	I have frequently been more active than usual 3	I am constantly active or on the go all the time 4

9.4 Appendix D: Quick Inventory of Depressive Symptoms

Quick Inventory of Depressive Symptoms (QIDS)

*Please circle the response (0-3) to **each item** that best describes you for the **past seven days**.*

Items	0	1	2	3
1: Falling asleep	I never take longer than 30 minutes to fall asleep 0	I take at least 30 minutes to fall asleep, less than half the time 1	I take at least 30 minutes to fall asleep, more than half the time 2	I take more than 60 minutes to fall asleep, more than half the time 3
2: Sleep during the night	I do not wake up at night 0	I have a restless, light sleep with a few brief awakenings each night 1	I wake up at least once a night, but I go back to sleep easily 2	I awaken more than once a night and stay awake for 20 minutes or more, more than half the time 3
3: Waking up too early	Most of the time, I awaken no more than 30 minutes before I need to get up 0	More than half the time, I awaken more than 30 minutes before I need to get up 1	I almost always awaken at least one hour or so before I need to, but I go back to sleep eventually 2	I awaken at least one hour before I need to, and can't go back to sleep 3
4: Sleeping too much	I sleep no longer than 7-8 hours/night, without napping during the day 0	I sleep no longer than 10 hours in a 24-hour period including naps 1	I sleep no longer than 12 hours in a 24-hour period including naps 2	I sleep longer than 12 hours in a 24-hour period including naps 3
5: Feeling sad	I do not feel sad 0	I feel sad less than half the time 1	I feel sad more than half the time 2	I feel sad nearly all of the time 3

6: Decreased appetite	There is no change in my usual appetite 0	I eat somewhat less often or lesser amounts of food than usual 1	I eat much less than usual and only with personal effort 2	I rarely eat within a 24-hour period, and only with extreme personal effort or when others persuade me to eat 3
7: Increased appetite	There is no change in my usual appetite 0	I feel a need to eat more frequently than usual 1	I regularly eat more often and / or greater amounts of food than usual 2	I feel driven to overeat both at mealtime and between meals 3
8: Decreased weight (within the last two weeks)	I have not had a change in my weight 0	I feel as if I've had a slight weight loss 1	I have lost 2 pounds or more 2	I have lost 5 pounds or more 3
9: Increased weight (within the last two weeks)	I have not had a change in my weight 0	I feel as if I've had a slight weight gain 1	I have gained 2 pounds or more 2	I have gained 5 pounds or more 3
10: Concentration/ decision making	There is no change in my usual capacity to concentrate or make decisions 0	I occasionally feel indecisive or find that my attention wanders 1	Most of the time, I struggle to focus my attention or to make decisions 2	I cannot concentrate well enough to read or cannot make even minor decisions 3
11: View of myself	I see myself as equally worthwhile and deserving as other people 0	I am more self-blaming than usual 1	I largely believe that I cause problems for others 2	I think almost constantly about major and minor defects in myself 3

12: Thoughts of death or suicide	I do not think of suicide or death 0	I feel that life is empty or wonder if it's worth living 1	I think of suicide or death several times a week for several minutes 2	I think of suicide or death several times a day in some detail, or I have made specific plans for suicide or have actually tried to take my life 3
13: General interest	There is no change from usual in how interested I am in other people or activities 0	I notice that I am less interested in people or activities 1	I find I have interest in only one or two of my formerly pursued activities 2	I have virtually no interest in formerly pursued activities 3
14: Energy level	There is no change in my usual level of energy 0	I get tired more easily than usual 1	I have to make a big effort to start or finish my usual daily activities (for example, shopping, homework, cooking or going to work) 2	I really cannot carry out most of my usual daily activities because I just don't have the energy 3
15: Feeling slowed down	I think, speak and move at my usual rate of speed 0	I find that my thinking is slowed down or my voice sounds dull or flat 1	It takes me several seconds to respond to most questions and I'm sure my thinking is slowed 2	I am often unable to respond to questions without extreme effort 3
16: Feeling restless	I do not feel restless 0	I'm often fidgety, wringing my hands, or need to shift how I am sitting 1	I have impulses to move about and am quite restless 2	At times, I am unable to stay seated and need to pace around 3

9.5 Appendix E: Beck Depression Inventory

Beck Depression Inventory (BDI)

This questionnaire asks about how you feel today. On this questionnaire are groups of statements. Please read each group of statements carefully, crossing the box next to the one statement in each group which *best* describes how you feel *today*. If several statements within a group seem to apply equally well, cross each one. *Be sure to read all the statements in each group before making your choice.*

1. ☐ - I do not feel sad.
   ☐ - I feel sad
   ☐ - I am sad all the time and I can't snap out of it.
   ☐ - I am so sad and unhappy that I can't stand it.

2. ☐ - I am not particularly discouraged about the future.
   ☐ - I feel discouraged about the future.
   ☐ - I feel I have nothing to look forward to.
   ☐ - I feel the future is hopeless and that things cannot improve.

3. ☐ - I do not feel like a failure.
   ☐ - I feel I have failed more than the average person.
   ☐ - As I look back on my life, all I can see is a lot of failures.
   ☐ - I feel I am a complete failure as a person.

4. ☐ - I get as much satisfaction out of things as I used to.
   ☐ - I don't enjoy things the way I used to.
   ☐ - I don't get real satisfaction out of anything anymore.
   ☐ - I am dissatisfied or bored with everything.

5. ☐ - I don't feel particularly guilty
   ☐ - I feel guilty a good part of the time.
   ☐ - I feel quite guilty most of the time.
   ☐ - I feel guilty all of the time.

6. ☐ - I don't feel I am being punished.
   ☐ - I feel I may be punished.
   ☐ - I expect to be punished.
   ☐ - I feel I am being punished.

7. ☐ - I don't feel disappointed in myself.
   ☐ - I am disappointed in myself.
   ☐ - I am disgusted with myself.
   ☐ - I hate myself.

8. ☐ - I don't feel I am any worse than anybody else.
☐ - I am critical of myself for my weaknesses or mistakes.
☐ - I blame myself all the time for my faults.
☐ - I blame myself for everything bad that happens.

9. ☐ - I don't have any thoughts of killing myself.
☐ - I have thoughts of killing myself, but I would not carry them out.
☐ - I would like to kill myself.
☐ - I would kill myself if I had the chance.

10. ☐ - I don't cry any more than usual.
☐ - I cry more now than I used to.
☐ - I cry all the time now.
☐ - I used to be able to cry, but now I can't cry even though I want to.

11. ☐ - I am no more irritated by things than I ever was.
☐ - I am slightly more irritated now than usual.
☐ - I am quite annoyed or irritated a good deal of the time.
☐ - I feel irritated all the time.

12. ☐ - I have not lost interest in other people.
☐ - I am less interested in other people than I used to be.
☐ - I have lost most of my interest in other people.
☐ - I have lost all of my interest in other people.

13. ☐ - I make decisions about as well as I ever could.
☐ - I put off making decisions more than I used to.
☐ - I have greater difficulty in making decisions more than I used to.
☐ - I can't make decisions at all anymore.

14. ☐ - I don't feel that I look any worse than I used to.
☐ - I am worried that I am looking old or unattractive.
☐ - I feel there are permanent changes in my appearance that make me look unattractive.
☐ - I believe that I look ugly.

15. ☐ - I can work about as well as before.
☐ - It takes an extra effort to get started at doing something.
☐ - I have to push myself very hard to do anything.
☐ - I can't do any work at all.

16. ☐ - I can sleep as well as usual.
☐ - I don't sleep as well as I used to.
☐ - I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
☐ - I wake up several hours earlier than I used to and cannot get back to sleep.

17. ☐ - I don't get more tired than usual.
☐ - I get tired more easily than I used to.
☐ - I get tired from doing almost anything.
☐ - I am too tired to do anything.

18. ☐ - My appetite is no worse than usual.
☐ - My appetite is not as good as it used to be.
☐ - My appetite is much worse now.
☐ - I have no appetite at all anymore.

19. ☐ - I haven't lost much weight, if any, lately.
☐ - I have lost more than five pounds.
☐ - I have lost more than ten pounds.
☐ - I have lost more than fifteen pounds.

20. ☐ - I am no more worried about my health than usual.
☐ - I am worried about physical problems like aches, pains, upset stomach, or constipation.
☐ - I am very worried about physical problems and it's hard to think of much else.
☐ - I am so worried about my physical problems that I cannot think of anything else.

21. ☐ - I have not noticed any recent change in my interest in sex.
☐ - I am less interested in sex than I used to be.
☐ - I have almost no interest in sex.
☐ - I have lost interest in sex completely.

9.6 Appendix F: Search criteria and selection process for eligible BDRN participants (studies one & two)

Table 9.1 Recruitment waves for study one and two

Recruitment Wave	Description	Number of Eligible Participants
1	• Located within a one hour drive of the University of Worcester • Actively engaged in current, on-going BDRN research	37
2	• Located within a two hour drive of the University of Worcester • Actively engaged in current, on-going BDRN research	90
3	• Located within a two hour drive of the University of Worcester • Returned the last BDRN questionnaire mailshot	73
4	• Located within a two hour drive of the University of Worcester • Joined BDRN within the last ten years	171

9.7 Appendix G: Chapter four (study one) interview recruitment email & interview confirmation email

Dear,

My name is Gemma McCullough and I am a member of BDRN currently carrying out my PhD research at the University of Worcester. I am researching the relationship between physical activity and mood in bipolar disorder. I would like to invite you as a member of BDRN to take part in an interview.

The interview would require me to visit you at home, however I can arrange a telephone interview if this is more convenient for you. The interview consists of a few questions about mood symptoms you might experience and general questions about your physical activity. The interview will likely last between thirty to forty minutes, and should not take more than an hour. I would be delighted to hear from you no matter how physically active or inactive you perceive yourself to be, as I am interested in understanding more about all aspects of physical activity, including physical inactivity.

If you would like to take part, I would be very grateful if you would reply to this email with a contact telephone number and some suitable times I can call you to tell you more about the research and arrange the interview.

Thank you for being a valued member of our on-going research into bipolar and related mood disorders.

Kind Regards,

Gemma McCullough
BDRN PhD Researcher
University of Worcester

Email: moodresearch@worc.ac.uk

If you would like to know a little more about me and the research I am doing, please feel free to visit my profile page on the BDRN website: http://bdrn.org/meet-the-team/gemma-mccullough/

Dear

Thank you once again for kindly agreeing to take part in our research into physical activity and mood in bipolar disorder. I am writing to confirm that I will be coming to visit you at home on **DATE** at **TIME**.

Please do not hesitate to contact me if you have any queries, or would like to change the time or date of my visit. My contact number is 07960050795.

I look forward to meeting you then.

Kind Regards,

Gemma McCullough
BDRN PhD Researcher
University of Worcester

Email: moodresearch@worc.ac.uk

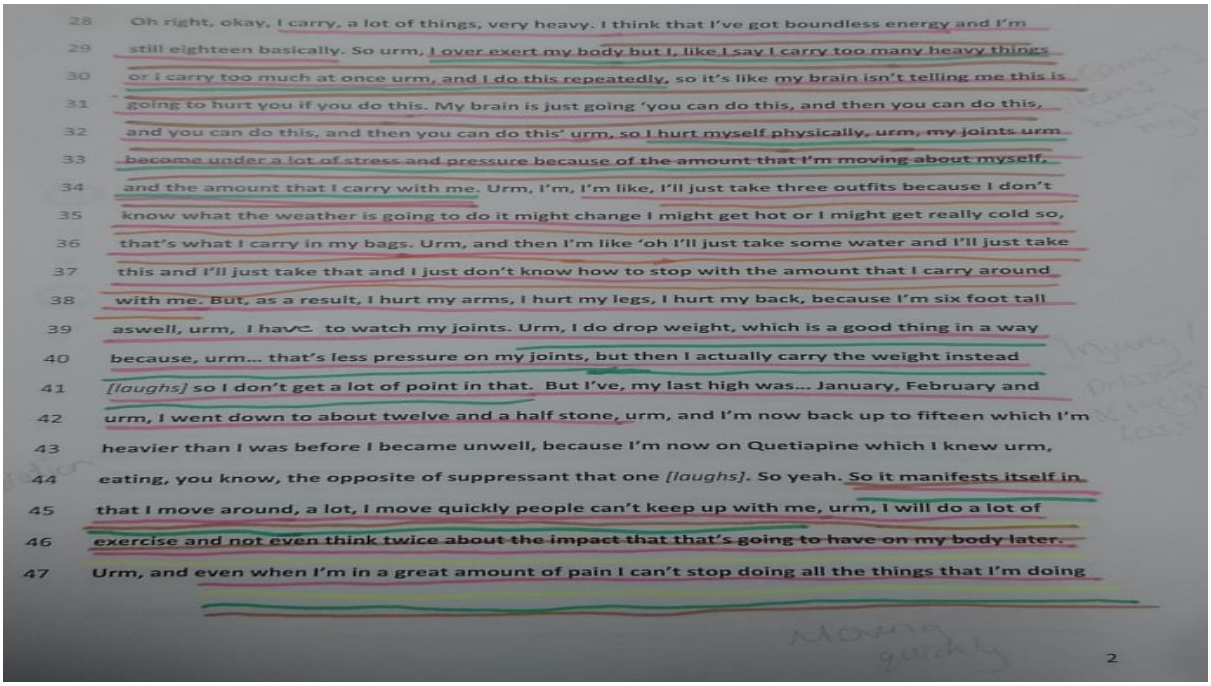
If you would like to know a little more about me and the research I am doing, please feel free to visit my profile page on the BDRN website: http://bdrn.org/meet-the-team/gemma-mccullough/

9.8 Appendix H: Chapter four (study one) examples of colour coding transcripts

Colour coding as part of ‘step 1:familiarisation of the data’ in study one’s thematic analysis helped to provide a focus for the subsequent stages of data analysis, and identify specific areas of interest. Data which indicated a relationship between PA and/or SB and mood was easily identified by the presence of two or more colours on the transcript, for example pink and yellow together highlighted data which related to both high mood, and specific exercise.

Table 9.2 Colour key for identifying key topics within interview transcripts

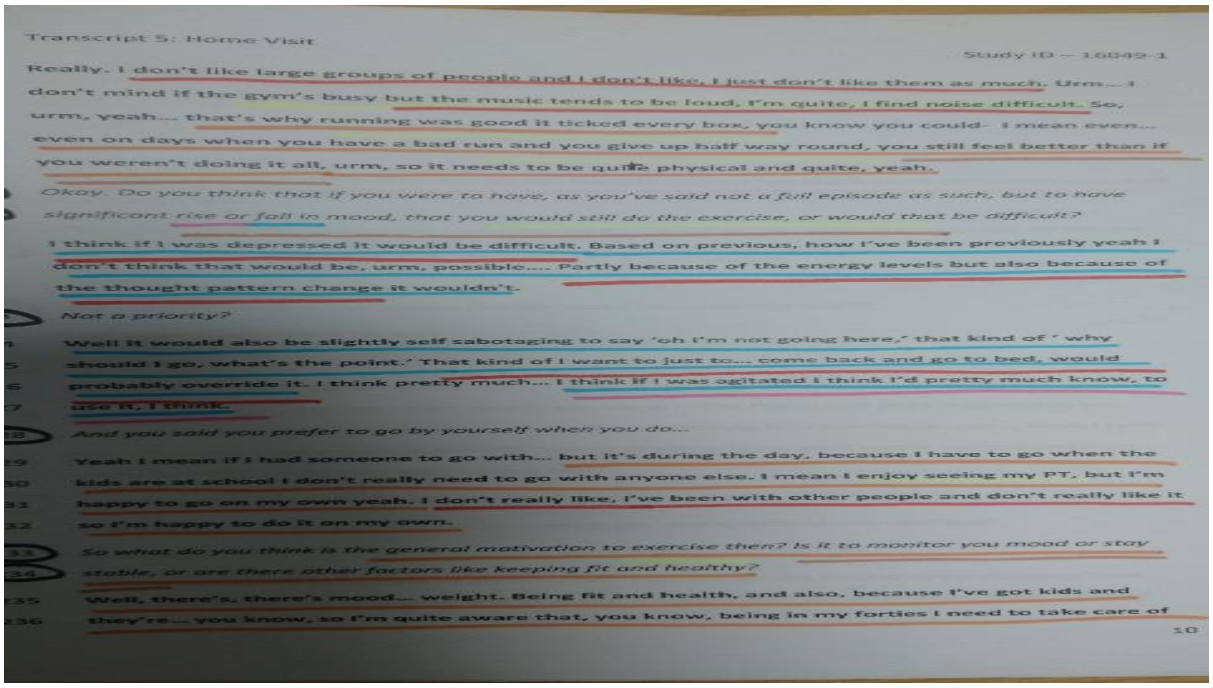
Topic	Colour key
High mood symptoms and experiences	
High mood triggers	
Low mood symptoms and experiences	
Low mood triggers	
Sedentary behaviour	
Physical activity	
Specific exercise	
Motivating factors for physical activity	
Barriers to physical activity	
Relationships between PA/SB & mood	



Oh right, okay, I carry, a lot of things, very heavy. I think that I've got boundless energy and I'm still eighteen basically. So urm, I over exert my body but I, like I say I carry too many heavy things or I carry too much at once urm, and I do this repeatedly, so it's like my brain isn't telling me this is going to hurt you if you do this. My brain is just going 'you can do this, and then you can do this, and you can do this, and then you can do this' urm, so I hurt myself physically, urm, my joints urm become under a lot of stress and pressure because of the amount that I'm moving about myself, and the amount that I carry with me. Urm, I'm, I'm like, I'll just take three outfits because I don't know what the weather is going to do it might change I might get hot or I might get really cold so, that's what I carry in my bags. Urm, and then I'm like 'oh I'll just take some water and I'll just take this and I'll just take that and I just don't know how to stop with the amount that I carry around with me. But, as a result, I hurt my arms, I hurt my legs, I hurt my back, because I'm six foot tall aswell, urm, I have to watch my joints. Urm, I do drop weight, which is a good thing in a way because, urm... that's less pressure on my joints, but then I actually carry the weight instead *[laughs]* so I don't get a lot of point in that. But I've, my last high was... January, February and urm, I went down to about twelve and a half stone, urm, and I'm now back up to fifteen which I'm heavier than I was before I became unwell, because I'm now on Quetiapine which I knew urm, eating, you know, the opposite of suppressant that one *[laughs]*. So yeah. So it manifests itself in that I move around, a lot, I move quickly people can't keep up with me, urm, I will do a lot of exercise and not even think twice about the impact that that's going to have on my body later. Urm, and even when I'm in a great amount of pain I can't stop doing all the things that I'm doing

2

Figure 9.1 Colour coding example one: Jane's Transcript



Transcript 5: Home Visit

Study ID – 16042-1

Really. I don't like large groups of people and I don't like, I just don't like them as much. Urm... I don't mind if the gym's busy but the music tends to be loud, I'm quite, I find noise difficult. So, urm, yeah... that's why running was good it ticked every box, you know you could- I mean even... even on days when you have a bad run and you give up half way round, you still feel better than if you weren't doing it all, urm, so it needs to be quite physical and quite, yeah.

Okay. Do you think that if you were to have, as you've said not a full episode as such, but to have significant rise or fall in mood, that you would still do the exercise, or would that be difficult?

I think if I was depressed it would be difficult. Based on previous, how I've been previously yeah I don't think that would be, urm, possible.... Partly because of the energy levels but also because of the thought pattern change it wouldn't-

Not a priority?

Well it would also be slightly self sabotaging to say 'oh I'm not going here,' that kind of ' why should I go, what's the point.' That kind of I want to just to... come back and go to bed, would probably override it. I think pretty much... I think if I was agitated I think I'd pretty much know, to use it, I think.

And you said you prefer to go by yourself when you do...

Yeah I mean if I had someone to go with... but it's during the day, because I have to go when the kids are at school I don't really need to go with anyone else. I mean I enjoy seeing my PT, but I'm happy to go on my own yeah. I don't really like, I've been with other people and don't really like it so I'm happy to do it on my own.

So what do you think is the general motivation to exercise then? Is it to monitor you mood or stay stable, or are there other factors like keeping fit and healthy?

Well, there's, there's mood... weight. Being fit and health, and also, because I've got kids and they're... you know, so I'm quite aware that, you know, being in my forties I need to take care of

10

Figure 9.2 Colour coding example two: Sarah's Transcript

9.9 Appendix I: Chapter four (study one) supplementary information on early theming

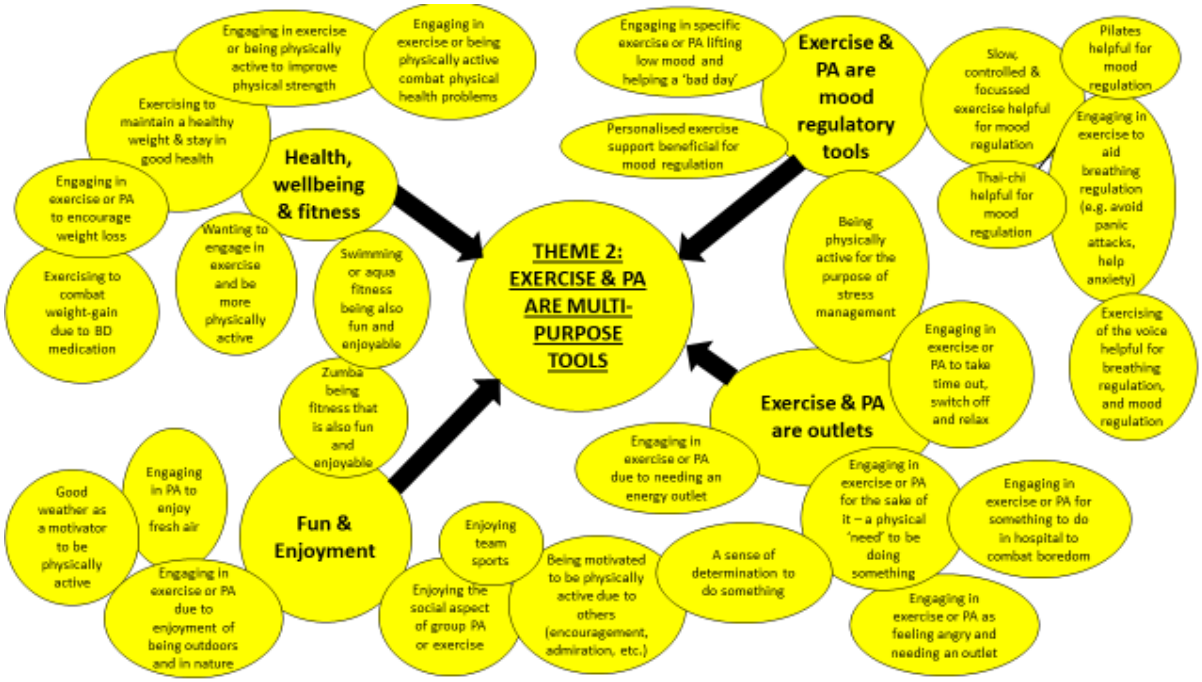
For each of the initial theme titles being considered, a thematic map was created to show the spread of key codes that had led to the development of that theme.

One of the first broad observations from the data was that it was difficult to distinguish from the interviews whether a change in mood was perceived to precede a change to PA or SB, or vice versa. Several participants used the ***'chicken or the egg'*** metaphor to describe their difficulty in identifying this, and so this became an initial theme to capture the complexity of perceived relationships between PA, SB and mood.

Thematic map 1: 'Chicken or the egg?'

Another early observation was of ***PA as a multi-purpose tool*** for participants. Wright et al. (2009) reported a theme of 'exercise as a mood regulatory tool', which the current study's data pertaining to specific exercise also identified, however PA

was additionally reported by various participants' as being useful for combating weight gain associated with mood stabilizing medication, for stress management, and for fun and enjoyment, among other reasons. As the perceived relationship of general PA and mood in BD has not yet been explored in depth, it seemed important at this stage of theming to identify PA being used for multiple purposes also, not just specific exercise.

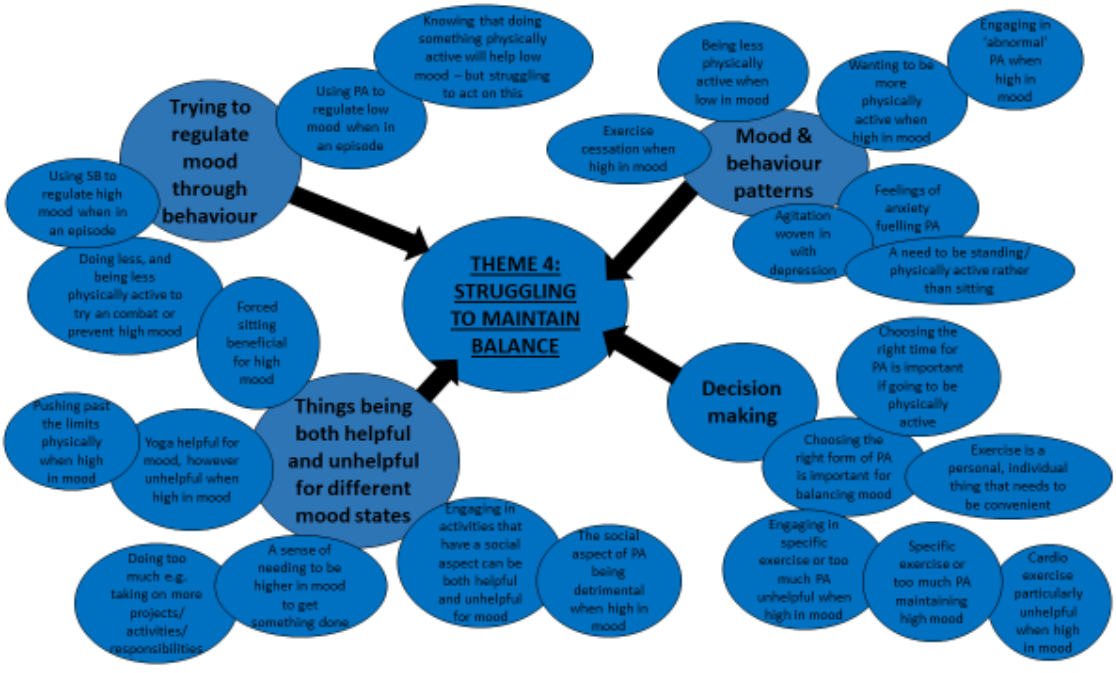


Thematic map 2: Exercise and PA are multi-purpose tools.

The data showed a perceived ***role and importance of routine***, for both mood regulation and engaging in regular PA as well as the benefit of incorporating SB within a routine, and so this was the next initial and second largest theme.

Thematic map 3: 'The role of routine'

Finally, it was identified that the data showed an overwhelming concept of balance, specifically ***struggling to maintain balance*** in relation to PA, SB and mood, becoming the final and largest initial theme.



Thematic map 4: 'struggling to maintain balance'

Themes 3 and 4 were considerably larger than the other two and so only the key codes contributing to that theme are presented in the thematic maps.

After revisiting the data it was felt that the ‘chicken or the egg’ theme title did not capture the full complexity of the perceived relationship between PA, SB and mood, and described only a small subset of the semantic interview quotes. Although it was interesting that several participants used the same metaphor, there was not the strength in the evidence to support this as a theme title. This complexity was better shaped by the theme title ‘PA and SB as an early warning sign’ which identifies that changes to mood are perceived to be closely related to changes in PA/SB, although the nature of this change is viewed as complex and uncertain by participants. Further, this change was viewed to be potentially influenced by the codes in thematic map 1 such as the identified mood triggers.

The theme name ‘PA and exercise as multi-purpose tools’ was discussed in terms of highlighting the positive impact of PA. Therefore, exploring the ‘impact of PA and SB’ as a theme would allow a focus on the data pertaining specifically to mood, and to compare this to evidence of the negative impact of PA and SB that was also present in the data rather than focusing on the solely positive impact described in previous research.

Routine was discussed and reviewed as a theme in relation to motivations and volitions, i.e. reasons for keeping to a routine of PA and SB, or not. It was identified that many participants provided reasons to do or not to do PA, and that these reasons were often connected to mood triggers, medication, or other volitions and motivations resulting in changing PA and SB levels. Although much of this evidence can be considered as barriers and facilitators of PA in particular, this was not an

appropriate theme name as it does little to explain the relationship trying to be explored, and participants were specifically asked about barriers and facilitators during the interview, making this as a theme name descriptive of the topic guide rather than interpretative of the interview data. Renaming ‘routine’ to ‘changing PA and SB levels’ and re-grouping the coded data allowed the thematic analysis to take a more focused direction in relation to the aim of this study to explore the relationship of PA, SB and mood rather than a surface level observation of routine as being important.

The concept of balance remained as a theme that connected the above three main themes together, and broadly summarised the codes and connectedness of these as an overarching theme. It was felt that although the reviewing of theme titles and code groupings allowed for a more distinct view of the overall data, the connectedness of the themes and their codes should not be ignored. It seemed important to accept this connectedness and work with it in the subsequent defining of theme titles rather than trying to force codes into completely distinct themes. Thought around the meaning of the codes and how they described participants’ perceptions of mood in relation to PA and SB identified balance as a key concept, and something that participants described as always trying to maintain, or trying to get back to. This explains why the initial theme of ‘struggling to maintain balance’ was the largest theme grouping from the initial searching for themes and why it was difficult to put some quotes into other themes that would also have fit in here. Therefore, the overarching theme was a development from ‘struggling to maintain balance’ to ‘trying to maintain balance’ to represent that this process underpins the perceived relationship between PA, SB and mood.

9.10 Appendix J: Chapter five (study two) recruitment email, information leaflet & confirmation email

Dear,

My name is Gemma McCullough and I am a member of BDRN currently carrying out my PhD research at the University of Worcester. I am researching the relationship between physical activity and mood in bipolar disorder.

As a member of BDRN, I would like to invite you to take part in this research and have included a leaflet below with information on the research. Taking part would involve wearing a small activity monitor for a week and answering a couple of short questionnaires on physical activity and mood symptoms.

I would be delighted to hear from you no matter how physically active or inactive you perceive yourself to be, as I am interested in understanding more about all aspects of physical activity, including physical inactivity.

If you would like to take part, I would be very grateful if you would reply to this email with a contact telephone number and some suitable times I can call you to tell you more about the research.

Thank you for being a valued member of our on-going research.

Kind Regards,

Gemma McCullough
BDRN PhD Researcher
University of Worcester

Email: moodresearch@worc.ac.uk

Bipolar Disorder BDRN Research Network

University of Worcester

If you would like to know a little more about me and the research I am doing, please feel free to visit my profile page on the BDRN website: http://bdrn.org/meet-the-team/gemma-mccullough/

Thank you for taking the time to read this leaflet and for considering taking part in this research study.

The BDRN Research Team

University of Worcester

Bipolar Disorder BDRN Research Network

Withdrawing

We will ask you to wear the ActivPAL for 7 consecutive days. However, you can take off the device or stop taking part at any time without having to give a reason.

How to take part

If you would like to take part in this research or would like any further information, please contact us and we would be delighted to speak with you.

☎ 01905 54 2880

💻 moodresearch@worc.ac.uk

Bipolar Disorder BDRN Research Network

Bipolar Disorder BDRN Research Network

Physical Activity and Mood Research Invitation Leaflet

Physical activity and mood in bipolar disorder

Relationships between physical activity levels and mood in bipolar disorder are not well understood. We are particularly interested in finding out how physical activity may affect, or be affected by, changes in mood.

We are asking BDRN participants who have taken part in our research into bipolar disorder if they would be willing to help us with our research into physical activity levels and mood.

Potential benefits

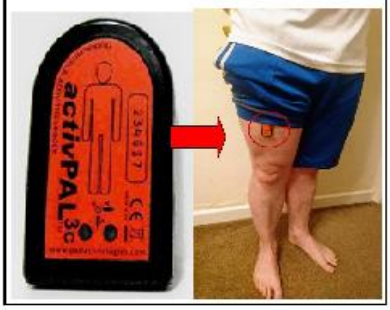
We hope to learn more about the role of physical activity levels in bipolar disorder, as this could be useful for identifying and predicting mood symptoms, and potentially improve the treatment of bipolar disorder.

What does taking part involve?

We will contact you to arrange delivery of a thigh-worn activity monitoring device called an ActivPAL (see images below).

The ActivPAL is a small, flat, non-invasive device that is made waterproof using a waterproof dressing which we will provide. You therefore do not need to remove the device for showering or bathing.

We will ask you to wear the device for **7 consecutive days**, and provide you with instructions on how to change the waterproof dressing. This should be done every 2-3 days.



We will also ask you to complete daily:

- A sleep and mood log (5 minutes total)

And at the end of the 7-day period:

- A short physical activity questionnaire (5 minutes)
- Two short mood questionnaires (5 minutes in total)

We will arrange for the free return of the ActivPAL device and questionnaires.

Am I eligible to take part?

If you are able to walk unaided, do not have broken or sensitive skin on your thigh, and have not had a reaction to a plaster or similar dressing in the past, then you are able to take part.

Even if you do not think you are very physically active, we would still like to invite you to take part, as it is important for us to understand more about various levels of activity, whether or not you play sports or exercise.

Dear,

Thank you once again for kindly agreeing to take part in our research into physical activity and mood in bipolar disorder. I am writing to confirm that your activity monitor and study pack will be sent to your home address via Royal Mail special delivery. It will arrive with you on **DATE before 1.00pm** and will require a signature upon receipt**.** I will follow up this delivery with a phone call in the afternoon to make sure you have received your monitor and study pack and to answer any questions you may have, but please do feel free to contact me at any time once it arrives if you have any questions.

Your activity monitor will start recording at midnight on the day you receive your ActivPAL, so please put the activity monitor on before you go to bed. 'Day one' in your study pack will therefore be **DATE**.

Please do not hesitate to contact me if you have any queries, or would like to change the date of this delivery. My contact number is 07960050795.

I look forward to speaking with you again soon,

Kind Regards,

Gemma

Gemma McCullough
BDRN PhD Researcher
University of Worcester

Email: moodresearch@worc.ac.uk

If you would like to know a little more about me and the research I am doing, please feel free to visit my profile page on the BDRN website: http://bdrn.org/meet-the-team/gemma-mccullough/

9.11 Appendix K: Chapter five (study two) ActivPAL3 instructions & guidance

Using the ActivPAL: instructions and guidance

The ActivPAL is to be worn on the front of the upper thigh. Therefore, you may wish to shave the hair from the thigh where the device will be worn to avoid any discomfort when removing the waterproof dressing.

In addition to the ActivPAL device you have the following:

- ActivPAL waterproof sleeves
- Strips of waterproof dressing

How to apply the ActivPAL and waterproof dressing:

1. Fully unroll the waterproof sleeve over the curved end of the ActivPAL.

2. Snip off the open end of the waterproof sleeve and fold this over the black side of the ActivPAL.

3. Place the now covered ActivPAL onto the front of your upper thigh so that the curved end of the orange side of the ActivPAL is facing upwards towards your hip. The black side of the device should be against your thigh.

4. Remove the backing sheet (side 1) from the waterproof dressing strip.

5. Stick this (side 1) over the ActivPAL so that the dressing covers the whole of the ActivPAL on all sides.

6. You can now peel away both halves of the top cover of the dressing (side 2), sealing in the ActivPAL to your thigh.

Important Information:

- The ActivPAL will flash orange until it starts recording. The recording will start at midnight on the day you receive your device. The device will then flash green every so often to show it is recording. If you think the device is not flashing at all, please contact me using the contact information below.

- The dressing should provide a continuous waterproof attachment for up to 7 days. However, you may wish to change the dressing every 2-3 days and monitor the dressing daily. You can move the device to the other thigh or to a different location along the midline of the same thigh when changing the dressing.

- Although the dressing is waterproof, you should remove the device before going swimming as prolonged immersion in water may cause the waterproof seal on the dressing to weaken.

- If you have any questions, please contact me by calling or texting me on **07960050795**, or alternatively you can email me on **moodresearch@worc.ac.uk**

9.12 Appendix L: Chapter five (study two) study pack (first three pages)

Activity and Mood Monitoring Study

This pack contains:

- A daily sleep and mood log. There are sections to be completed in the morning and evening each day (approx. 5 minutes).

- 3 x short questionnaires to be completed at the end of the 7-day period (approx. 10 minutes total).

In addition to this pack, you have been provided with:

- An ActivPAL (activity monitoring device)
- 5 x waterproof sleeves
- 5 x waterproof dressings (Tegaderm™)
- Instructions and guidance on changing the waterproof dressing
- A pre-stamped returns envelope (including a protective pocket for the ActivPAL)

Thank you again for volunteering to participate in this research

If you have any questions, please contact me by calling or texting me on 07960050795, or alternatively you can email me on moodresearch@worc.ac.uk

University of Worcester

Bipolar Disorder BDRN Research Network

Daily Sleep and Mood Log: Instructions and Guidance

Please complete the sleep and mood log each day during this research, it takes less than five minutes a day to complete. You are asked to complete some questions in the **morning** (just after you wake up) and some questions in the **evening** (just before you go to bed).

- Day one is the day after you put on your ActivPAL device. The days are already dated for you in the log to help you keep track of each day. Please use a new page for each day.

- In the morning, you are asked for the time you went to bed and fell asleep the night before.

- In the evening, you are asked about the times of any naps taken, and any times you removed your ActivPAL device that day (e.g. to change the waterproof dressing). You are also asked about your mood for that day. There is also space for you to describe, if you think it relevant, anything that might have contributed to your mood and physical activity levels each day. This is optional, but it is helpful for us to get as much detail as possible about your day-to-day experiences.

- You may find it helpful to leave this log by your bed to remind you to complete it when you wake up each day and before you go to bed each night.

- **On the last day of the research** (day seven) please remove the ActivPAL device before you go to sleep. There is a question on day seven of this log asking for the time you removed the device.

  Additional Information:

  For this research, it would be helpful for us to know what medication(s) (if any) you are currently using. If you would be willing to provide this, please list your current medications and the dosage below:

  _____

  _____

  _____

  _____

  If you would be willing, it would also be helpful for us to know your current height and

  weight.

  Height: _____ Ft/in or cm (please delete as appropriate)

  Weight:_____ St/lbs or kg (please delete as appropriate)

Daily Sleep and Mood Log

DAY ONE – date to be completed on: **_____**

Morning

What time did you go to bed **last night**? (E.g. 10.00pm) _____

What time did you fall asleep **last night**? (E.g. 10.30pm) _____ (approximately)

Evening

Please give the times of any naps you had **today** (E.g. 3.00pm to 4.00pm)

_____

Please give the times of any removal of your device **today** (E.g. 9.00pm to 9.10pm)

_____

Please rate to what extent each of the following words describe your mood **today.** Please rate every mood item only once each day using a (✓) on a scale from 'not at all', to 'very much'.

	Not at all						**Very much**
Anxious	◯	◯	◯	◯	◯	◯	◯
Elated	◯	◯	◯	◯	◯	◯	◯
Sad	◯	◯	◯	◯	◯	◯	◯
Angry	◯	◯	◯	◯	◯	◯	◯
Irritable	◯	◯	◯	◯	◯	◯	◯
Energetic	◯	◯	◯	◯	◯	◯	◯

Please describe any factors that you feel contributed to your mood **today**: (optional)

_____

_____

_____

Please describe any factors that you feel contributed to your physical activity levels **today**: (optional)

_____

_____

_____

9.13 Appendix M: Chapter five (study two) postal delivery cover letter

Dear NAME,

Thank you again for kindly agreeing to take part in our activity and mood monitoring study.

Please find enclosed your study pack and your ActivPAL activity monitor. Please take the time to read the instructions and guidance on completing the daily sleep and mood log (on the inside page of your study pack) and the additional instructions and guidance for attaching the activity monitor using the waterproof dressing provided.

Your ActivPAL is in the protective pouch at the back and is wrapped in a protective film, you do not need to remove this. Your ActivPAL will occasionally flash an orange light when you receive it, this indicates that it is programmed and ready to start. **Your ActivPAL will start recording at midnight tonight, so please put the ActivPAL on before you go to bed tonight.** The ActivPAL will start flashing green around every six seconds once it starts recording. Please let me know if your device does not start flashing green.

I will follow up this letter with a brief telephone call this afternoon to make sure you have received your study pack and to answer any questions you may have, however if you would prefer to contact me sooner please feel free to call or text me on **07960050795.**

I will also follow up with a brief telephone call on the final day of the study, **DATE,** to see how you got on and to remind you to complete the three short questionnaires at the back of the study pack. Once completed, please put the ActivPAL back into the protective pouch, and then put this and the study pack in the pre-stamped envelope enclosed to post back to us.

Once we have received your ActivPAL, we will send you a copy of the output so that you can take a look at your physical activity for the week.

Kind regards,

Gemma McCullough

BDRN PhD Researcher

University of Worcester

Bipolar Disorder BDRN Research Network

9.14 Appendix N: Chapter five (study two) participant thank you letter

Dear,

Thank you once again for kindly taking part in our activity and mood research.

Please find enclosed a copy of your daily ActivPAL output produced by the activity monitor.

I have included some guidance below on how to read and interpret this output summary.

Kind regards,

Gemma McCullough

BDRN PhD researcher

Interpreting your ActivPAL output

- Due to the programming on the ActivPAL recording, your output will not necessarily start on 'Day 1'. Please refer to the date on the top of each page to view what date each daily recording took place.
- Each line represents an hour in time. The time in hours is listed vertically down the left hand side of the output, and the minute by minute day horizontally along each line.

Yellow represents time spent sitting or lying down (sedentary).

Green represents time spent standing.

Red represents time spent walking and/or other physical movement

- At the end of each line, there are summary figures for that hour (time spent sitting/lying, time spent standing, and steps).
- There is also an activity score, shown as 'MET.h'. This number refers to the average estimated energy expenditure for that hour (the amount of energy you've used). A number of 1.5 or less is considered to be time spent mostly sedentary (sitting or lying down) during that hour.

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9.15 Appendix O: Chapter five (study two) supplementary analyses – agreement between two methods for removal of sleep time from raw ActivPAL3 data.

The ActivPAL3 data does not distinguish between sitting/lying whilst awake or asleep, and so the initial data processed as time spent in SB in PAL Technologies (PALanalysis-V8, palt.com) includes sleep time which needs to be removed to produce the actual time spent in SB.

The two methods of removing sleep time from raw ActivPAL were:

- Using a validated waking wear algorithm (Wrinker et. al. 2016) to detect and remove time spent asleep from the ActivPAL3 SB data.
- Using participants' self-reported sleep times (from the sleep log) to manually calculate time spent asleep for each 24/h period, and then deducting this from the total time spent in SB per 24/h period.

Pearson's parametric correlation test was carried out to determine the relationship between the above two methods (as time spent in SB calculated from both above methods met parametric assumptions). The test showed a positive relationship with large strength (Cohen, 1988) ($r=0.763$, $n=51$, $p<0.001$) between sleep removal using the validated algorithm, and sleep removal using manual sleep log calculations.

Agreement between these two methods was assessed using a Bland-Altman plot (Bland & Altman, 1986) (figure 9.1) which plots the difference of the two methods, against the mean of the two methods (N=51).

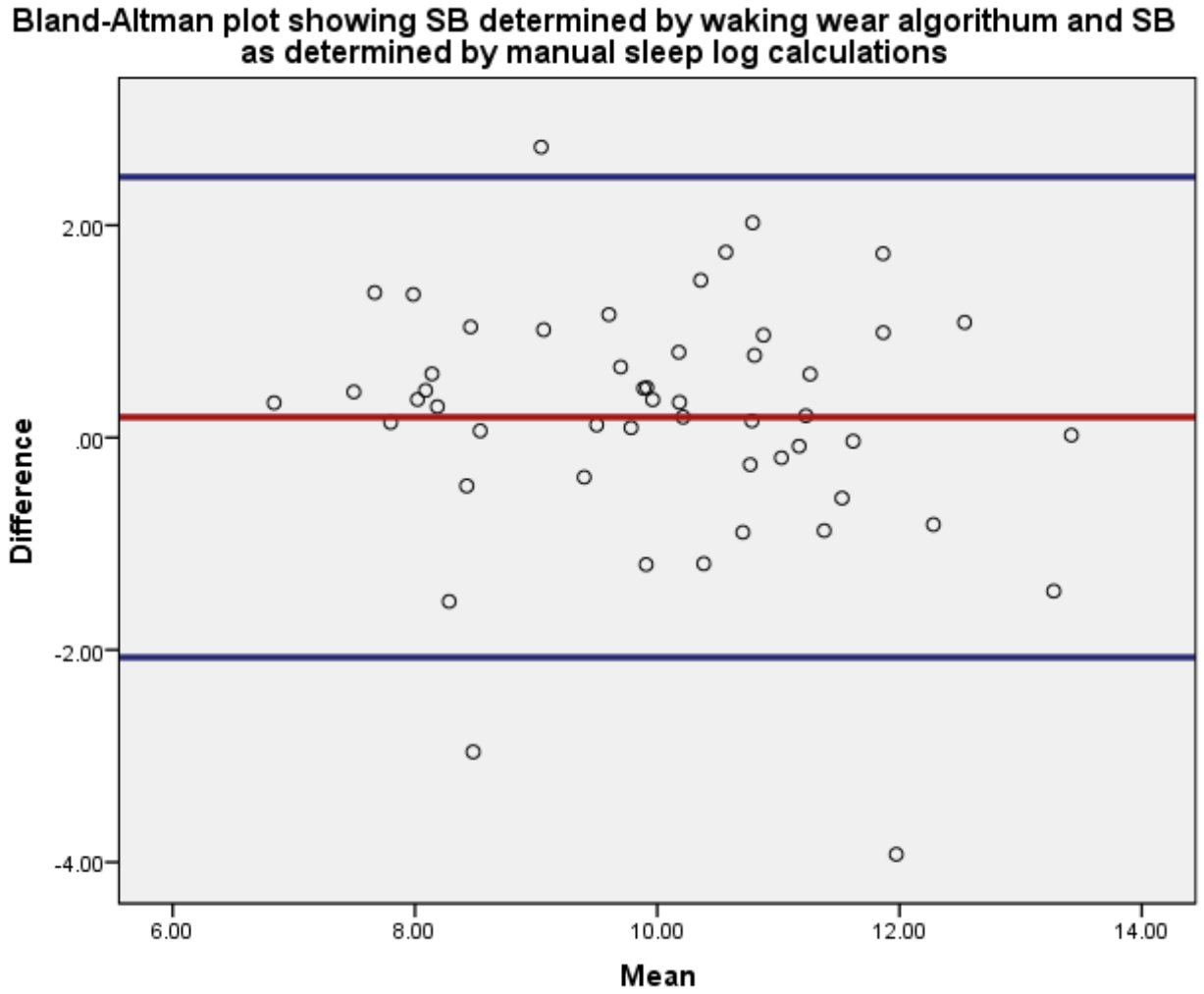

Figure 9.3 Bland-Altman plot showing levels of agreement between two methods: the validated waking wear algorithm (Wrinker et al. 2016) and manual sleep log calculations for removing sleep time from time spent in SB determined by the ActivPAL3 (N=51)

In figure 9.1 the red line represents the overall mean (0.19(±1.15)) and the blue lines represent the upper and lower confidence intervals (upper=2.45, lower= -2.07). The points on figure 9.1 are scattered all over the graph, which indicates that there is no consistent bias in either the validated algorithm or sleep-log calculation method, i.e. neither typically over or underestimates time spent in SB compared to the other. There are slightly more points which fall above the mean line (red) than below. All

points except three in figure 9.1 are within the confidence interval limits of the plot, indicating acceptable levels of agreement between the two methods.

To further assess agreement between sleep removal using the validated algorithm, and sleep removal using manual sleep log calculations, a linear regression was carried out using the difference of the two measures against the mean of the two measures which was non-significant ($F=1.192(1, 49)$, $p=0.280$)) indicating that there was no proportional bias between the two measures (adjusted r-squared=0.024, beta=-0.114).

9.16 Appendix P: Chapter five (study two) additional analyses – identifying confounding factors

Gender

Table 9.3 Chapter five non-significant analyses exploring differences between males & females

PA, SB & mood variables	Differences between males & females (M=males/F=females)
Time spent standing (hrs)	t(49)=-0.14, p=0.674 M= 4.06(1.40) F= 4.13(1.55)
Time spent stepping (hrs)	t(49)=1.60, p=0.924 M= 1.86(0.69) F= 1.54(0.63)
Time spent in light PA (hrs)	t(49)=-0.35, p=0.753 M= 0.65(0.26) F= 0.68(0.28)
Number of SB to upright transitions	t(49)=-1.77, p=0.459 M= 47.72(17.47) F= 56.29(15.29)
Time spent in SB (hrs)	t(49)=1.27, p=0.169 M= 10.38(1.46) F= 9.72(1.84)
Number of SB bouts lasting 0-30mins	t(49)=-1.77, p=0.628 M= 42.05(18.58) F= 51.20(16.49)
Time spent in SB bouts lasting 0-30mins (hrs)	t(49)=0.061, p=0.088 M= 4.48(1.68) F= 4.46(1.04)
Number of SB bouts lasting 30-60mins	t(49)=1.62, p=0.498 M= 3.91(1.34) F= 3.35(1.04)
Time spent in SB bouts lasting 30-60mins (hrs)	t(49)=1.56, p=0.524 M= 2.74(0.94) F= 2.36(0.75)
Number of SB bouts lasting 60-120mins	t(49)=0.31, p=0.478 M= 1.74(1.04) F= 1.65(0.94)
Time spent in SB bouts lasting 60-120mins (hrs)	t(49)=0.38, p=0.405 M= 2.39(1.46) F= 2.23(1.28)
Number of SB bouts lasting 120mins	U=246.50 p=0.490 M= Md:0.29 (IQR:0.04, 0.54) F= Md:0.25 (IQR:0.00, 0.43)
Time spent in SB bouts lasting 120mins (hrs)	U=257.00 p=0.638 M= Md:0.63 (IQR:0.08, 1.20) F= Md:0.61 (IQR:0.00, 0.95)
Anxiety	U=254.50, p=0.595 M= Md:2.50 (IQR:2.00, 3.75) F= Md:2.00 (IQR:1.00, 4.00)
Anger	U=223.50, p=0.152 M= Md:1.00 (IQR:1.00, 2.00) F= Md:1.00 (IQR:1.00, 1.00)
Sadness	U=238.50, p=0.371 M= Md:1.00 (IQR:1.00, 3.00) F= Md:2.00 (IQR:1.00, 4.00)
Irritable	U=270.50, p=0.842 M= Md:2.50 (IQR:1.00, 4.75) F= Md:2.00 (IQR:1.00, 3.00)
Total score for depression (QIDS)	U=199.00, p=0.099 M= Md:6.00 (IQR:3.00, 7.75) F= Md:9.00 (IQR:4.00, 15.00)
Total score for (hypo)mania (ASRM)	U=206.50, p=0.124 M= Md:2.00 (IQR:0.25, 9.00) F= Md:1.00 (IQR:0.00, 4.00)

Age

Table 9.4 Chapter five non-significant analyses exploring correlations with age (yrs)

PA, SB & mood variables	Correlations with age (yrs)
Time spent standing (hrs)	r=0.032, n=51, p=0.826,
Time spent stepping (hrs)	r=0.033, n=51, p=0.818
Number of steps taken	r=0.005, n=51, p=0.972
Time spent in light PA (hrs)	r=0.062, n=51, p=0.663
Time spent in MVPA (hrs)	r=0.050, n=51, p=0.729
Number of SB to upright transitions	r=-0.210, n=51, p=0.139
Time spent in SB (hrs)	r=0.140, n=51, p=0.326
Number of SB bouts	r=-0.209, n=51, p=0.141
Number of SB bouts lasting 0-30mins	r=-0.213, n=51, p=0.133
Time spent in SB bouts lasting 0-30mins (hrs)	r=-0.083, n=51, p=0.561
Number of SB bouts lasting 30-60mins	r=0.110, n=51, p=0.444
Time spent in SB bouts lasting 30-60mins (hrs)	r=0.149, n=51, p=0.298
Number of SB bouts lasting 60-120mins	r=0.123, n=51, p=0.390
Time spent in SB bouts lasting 60-120mins (hrs)	r=0.145, n=51, p=0.309
Number of SB bouts lasting 120mins	r=0.194, n=51, p=0.173
Time spent in SB bouts lasting 120mins (hrs)	r=0.136, n=51, p=0.343
Anxiety	r=-0.038, n=51, p=0.791
Anger	r=0.033, n=51, p=0.816
Sadness	r=0.009, n=51, p=0.947
Irritable	r=-0.157, n=51, p=0.273
Elation	r=0.160, n=51, p=0.262
Total score for depression (QIDS)	r=-0.112, n=51, p=0.435
Total score for (hypo)mania (ASRM)	r=0.231, n=51, p=0.102

A significant positive association was identified between age and feeling ‘energetic’ (r=0.331, n=51, p=0.018), i.e., older participants felt more ‘energetic’.

Medication

Mood stabilizers

Table 9.5 Chapter five non-significant analyses exploring differences between those using & not using mood stabilizers

PA, SB & mood variables	Differences between those using & not using mood stabilizers (y=yes, n=no)
Time spent standing (hrs)	t(39)=-1.63, p=0.611 Y= 4.55(1.45) N= 3.77(1.61)
Time spent stepping (hrs)	t(39)=-1.52, p=0.295 Y= 1.80(0.65) N= 1.48(0.69)
Number of steps taken	t(39)=-1.58 Y=4258.88(1867.26) N=3396.78(1578.39)
Time spent in light PA (hrs)	t(39)=0.61, p=0.223 Y= 0.70(0.26) N= 0.64(0.31)
Time spent in MVPA (hrs)	t(39)=(-1.81), p=0.813 Y= 1.10(0.51) N= 0.84(0.40)
Number of SB to upright transitions	t(39)=-0.47, p=0.123 Y= 54.00(17.62) N= 51.69(13.33)
Time spent in SB (hrs)	t(39)=1.41, p=0.188 Y= 9.36(1.77) N= 10.10(1.54)
Number of SB bouts	t(39)=-0.46, p=0.122 Y= 54.18(17.61) N= 51.89(13.33)
Number of SB bouts lasting 0-30mins	t(39)=-0.58, p=0.201 Y= 49.05(18.60) N= 45.98(14.54)
Time spent in SB bouts lasting 0-30mins (hrs)	t(39)=0.05, p=0.282 Y= 4.33(1.13) N= 4.35(1.03)
Number of SB bouts lasting 30-60mins	t(39)=1.56, p=0.860 Y= 3.33(1.19) N= 3.91(1.16)
Time spent in SB bouts lasting 30-60mins (hrs)	t(39)=-1.51, p=0.797 Y= 2.35(0.83) N= 2.73(0.80)
Number of SB bouts lasting 60-120mins	t(39)=0.58, p=0.113 Y= 1.59(0.79) N= 1.75(1.03)
Time spent in SB bouts lasting 60-120mins (hrs)	t(39)=0.62, p=0.150 Y= 2.12(1.06) N= 2.36(1.36)
Number of SB bouts lasting 120mins	U=196.00, p=0.729 Y= Md:0.20 (IQR:0.00, 0.30) N= Md:0.25 (IQR:0.00, 0.43)
Time spent in SB bouts lasting 120mins (hrs)	U= 194.00, p=0.692 Y= Md: 0.55 (IQR:0.00, 0.87) N= Md: 0.55 (IQR:0.00, 1.00)
Anxiety	U=192.00, p=0.646 Y= Md:2.00 (IQR:1.00, 3.25) N= Md: 2.00 (IQR:1.00, 3.00)
Anger	U=167.00, p=0.158 Y= 1.00 (IQR:1.00, 1.00) N= 1.00 (IQR:1.00, 2.00)

Irritable	U=193.00, p=0.663 Y= Md:2.00 (IQR:1.00, 3.25) N= Md:2.00 (IQR:1.00, 3.00)
Elation	U=204.00, p=0.883 Y= Md:1.00 (IQR:1.00, 3.00) N= Md:1.00 (IQR:1.00, 2.00)
Energetic	U=173.50, p=0.338 Y= Md:2.00 (IQR:1.75, 4.00) N= Md:2.00 (IQR:1.00, 3.00)
Total score for depression (QIDS)	U=207.50, p=0.969 Y= Md:6.50 (IQR:4.00, 10.50) N= Md:9.00 (IQR:2.00, 14.00)
Total score for (hypo)mania (ASRM)	U=185.50, p=0.525 Y= Md:1.00 (IQR:0.00, 3.25) N= Md:0.00 (IQR:0.00, 4.00)

Significant differences between those using and not using mood stabilizers were identified for ratings of 'sadness' (U=117.50, p=0.010), with those using a mood stabilizer reporting lower levels of symptom severity for 'sadness' (Md=1.00, IQR=1.00, 2.00) than those who did not report use (Md=3.00, IQR=1.00, 4.00).

Anti-psychotics

Table 9.6 Chapter five non-significant analyses exploring differences between those using and not using anti-psychotics

PA, SB & mood variables	Differences between those using & not using anti-psychotics (y=yes, n=no)
Time spent stepping (hrs)	t(39)=0.82, p=0.300 Y= 1.57(0.72) N= 1.74(0.63)
Number of steps taken	t(39)=0.42, p=0.329 Y= 3745.84(1995.45) N= 3978.58(1546.63)
Time spent in light PA (hrs)	t(39)=1.40, p=0.872 Y= 0.61(0.27) N= 0.74(0.29)
Time spent in MVPA (hrs)	t(39)=0.34, p=0.444 Y= 0.96(0.54) N= 1.01(0.41)
Number of SB to upright transitions	t(39)=-0.34, p=0.608 Y= 53.74(14.93) N= 52.01(16.69)
Time spent in SB (hrs)	t(39)=-0.73, p=0.809 Y= 9.89(1.80) N= 9.51(1.57)
Number of SB bouts	t(39)=-0.34, p=0.612 Y= 53.93(14.93) N= 52.47(16.66)
Number of SB bouts lasting 0-30mins	t(39)=-0.25, p=0.733 Y= 48.26(16.02) N= 46.97(17.79)
Time spent in SB bouts lasting 0-30mins (hrs)	t(39)=-0.92, p=0.671 Y= 4.49(1.10) N= 4.18(1.05)
Number of SB bouts lasting 30-60mins	t(39)=-0.10, p=0.192 Y= 3.80(1.39) N= 3.39(0.95)

Time spent in SB bouts lasting 30-60mins (hrs)	t(39)=-0.94, p=0.257 Y= 2.65(0.94) N= 2.40(0.69)
Number of SB bouts lasting 60-120mins	t(39)=-0.11, p=0.532 Y= 1.68(0.84) N= 1.65(0.98)
Time spent in SB bouts lasting 60-120mins (hrs)	t(39)=0.01, p=0.495 Y= 2.23(1.31) N= 2.23(1.31)
Number of SB bouts lasting 120mins	U=148.50, p=0.102 Y= Md:0.14 (IQR:0.00, 0.29) N= Md: 0.29 (IQR:0.14, 0.40)
Time spent in SB bouts lasting 120mins (hrs)	U=157.00, p=0.163 Y= Md: 0.40(IQR:0.00, 0.79) N= Md: 0.67(IQR:0.32, 0.98)
Anxiety	U=189.50, p=0.581 Y= Md:2.00 (IQR:1.00, 3.50) N= Md:2.00 (IQR:1.00, 3.00)
Anger	U=164.5, p=0.127 Y= Md:1.00 (IQR:1.00, 2.00) N= Md:1.00 (IQR:1.00, 1.00)
Sadness	U=195.50, p=0.683 Y= Md: 1.00 (IQR:1.00, 3.50) N= Md: 2.00 (IQR:1.00, 3.00)
Irritable	U=177.00, p=0.369 Y= Md:2.00 (IQR:1.00, 3.00) N= Md:2.00 (IQR:1.00, 3.50)
Elation	U=198.00, p=0.725 Y= Md: 1.00 (IQR:1.00, 2.50) N= Md: 1.00 (IQR:1.00, 2.00)
Energetic	U=169.00, p=0.269 Y= Md:2.00 (IQR:1.00, 2.50) N= Md:3.00 (IQR:1.25, 4.00)
Total score for depression (QIDS)	U=178.50, p=0.410 Y= Md:6.00 (IQR:3.50, 13.50) N= Md:8.50 (IQR:3.25, 15.75)
Total score for (hypo)mania (ASRM)	U=203.00, p=0.850 Y= Md:1.00 (IQR:0.00, 4.00) N= Md:1.00 (IQR:0.00, 3.75)

A significant difference of time spent standing (hrs) (t(39)=2.11, p=0.041) was identified, with those reporting anti-psychotic use spending less time standing (hrs) on average (mean=3.71(±1.53)) than those not reporting use (mean=4.70(±1.45)).

Anti-depressants

Table 9.7 Chapter five analyses exploring differences between those using & not using anti-depressants

PA, SB & mood variables	Differences between those using & not using anti-depressants (y=yes, n=no)
Time spent stepping (hrs)	t(39)=2.87** Y= mean=1.34 (±1.34) N= mean=1.90(±0.58)
Number of steps taken	t(38.33)=-3.26** Y= mean=2954.71(±1486.95) N= mean=4567.37(±1675.93)
Time spent standing (hrs)	t(39)=2.70** Y= mean=3.50(±1.50) N= mean=4.73 (±1.41)
Time spent in MVPA (hrs)	t(39)=3.48** Y= mean=0.72(±0.37) N= mean=1.18(±0.45)
Time spent in light PA (hrs)	t(39)=1.15, p=0.095 Y= 0.61(0.33) N= 0.72(0.25)
Number of SB to upright transitions	t(39)=0.45, p=0.617 Y= 51.66(16.61) N= 53.92(15.12)
Number of SB bouts	t(39)=0.45, p=0.683 Y= 51.88(16.56) N= 54.09(15.15)
Number of SB bouts lasting 0-30mins	t(39)=0.70, p=0.539 Y= 45.55(17.82) N= 49.25(15.99)
Time spent in SB bouts lasting 0-30mins (hrs)	t(39)=0.81, p=0.661 Y= 4.19(1.13) N= 2.37(0.81)
Number of SB bouts lasting 30-60mins	t(39)=-1.25, p=0.933 Y= 3.86(1.22) N= 3.39(1.22)
Time spent in SB bouts lasting 30-60mins (hrs)	t(39)=-1.39, p=0.847 Y= 2.73(0.83) N= 2.37(0.81)
Anxiety	U=195.50, p=0.755 Y= Md:2.00 (IQR:1.75, 3.00) N= Md:2.00 (IQR:1.00, 4.00)
Anger	U=188.50, p=0.532 Y= Md:1.00 (IQR:1.00, 1.25) N= Md:1.00 (IQR:1.00, 2.00)
Sadness	U=151.50, p=0.115 Y= Md:2.00 (IQR:1.00, 4.00) N= Md:1.00 (IQR:1.00, 3.00)
Irritable	U=190.50, p=0.651 Y= Md:2.00 (IQR:1.00, 3.25) N= Md:2.00 (IQR:1.00, 3.00)
Elation	U=194.50, p=0.712 Y= Md:1.00 (IQR:1.00, 2.00) N= Md:1.00 (IQR:1.00, 3.00)
Energetic	U=164.00, p=0.243 Y= Md: 2.00 (IQR:1.00, 3.25) N= Md:2.00 (IQR:2.00, 4.00)
Total score for depression (QIDS)	U=147.00, p=0.114 Y= Md:11.00 (IQR:5.00, 18.00) N= Md:6.00 (IQR:3.00, 9.00)

**p<0.05, **p<0.01, ***p<0.001*

Although significant differences were identified in Table 9.7 above between those using and not using anti-depressants on their PA ('time spent stepping,' 'number of steps taken,' 'time spent standing' and 'time spent in MVPA') as well as mood (total ASRM score for (hypo)mania) in those using and not using anti-depressants, this was not explored further as Table 5.13 (page 240) showed no significant associations between any PA variables and the ASRM total score for (hypo)mania.

Body Mass Index

Table 9.8 Chapter five non-significant analyses exploring correlations with BMI

PA, SB & mood variables	Correlations with BMI
Time spent standing (hrs)	r=-0.237, n=44, p=0.121
Number of SB to upright transitions	r=-0.165, n=44, p=0.284
Number of SB bouts	r=-0.164, n=44, p=0.289
Number of SB bouts lasting 0-30mins	r=-0.186, n=44, p=0.227
Time spent in SB bouts lasting 0-30mins (hrs)	r=-0.127, n=44, p=0.411
Number of SB bouts lasting 30-60mins	r=0.289, n=44, p=0.057
Time spent in SB bouts lasting 30-60mins (hrs)	r=0.257, n=44, p=0.092
Number of SB bouts lasting 60-120mins	r=0.209, n=44, p=0.173
Time spent in SB bouts lasting 60-120mins (hrs)	r=0.222, n=44, p=0.147
Anxiety	r=0.091, n=44, p=0.556
Anger	r=-0.004, n=44, p=0.981
Sadness	r=0.070, n=44, p=0.651
Irritable	r=0.054, n=44, p=0.729
Elation	r=-0.212, n=44, p=0.167
Total score for depression (QIDS)	r=0.104, n=44, p=0.501
Total score for (hypo)mania (ASRM)	r=0.125, n=44, p=0.418

Lifetime psychiatric history

Bipolar disorder sub-type

Table 9.9 Chapter five non-significant analyses exploring differences between BD sub-type

PA, SB & mood variables	Differences between those with BDI & BDII (1=BDI, 2=BDII)
Time spent standing (hrs)	t(49)=1.23, p=0.606 1= 4.35(1.57) 2= 3.83(1.38)
Time spent stepping (hrs)	t(49)=1.27, p=0.269 1= 1.75(0.62) 2= 1.52(0.69)
Number of steps taken	t(49)=1.44, p=0.608 1= 4145.03(1767.24) 2= 3452.40(1652.12)
Time spent in light PA (hrs)	t(49)=0.255, p=0.279 1= 0.68(0.26) 2= 0.66(0.29)
Time spent in MVPA (hrs)	t(49)=1.66, p=0.991 1= 1.07(0.48) 2= 0.86(0.43)
Number of SB to upright transitions	t(49)=0.28, p=0.305 1= 54.21(17.10) 2= 52.91(15.75)

Time spent in SB (hrs)	t(49)=-1.76, p=0.433 1= 9.53(1.89) 2= 10.37(1.48)
Number of SB bouts	t(49)=0.28, p=0.300 1= 54.41(17.12) 2= 53.13(15.72)
Number of SB bouts lasting 0-30mins	t(49)=0.39, p=0.374 1= 49.23(18.20) 2= 47.30(17.04)
Time spent in SB bouts lasting 0-30mins (hrs)	t(49)=-0.40, p=0.551 1= 4.40(1.36) 2= 4.54(1.15)
Number of SB bouts lasting 30-60mins	t(49)=-1.63, p=0.632 1= 3.28(1.17) 2= 3.08(1.11)
Time spent in SB bouts lasting 30-60mins (hrs)	t(49)=-1.81, p=0.784 1= 2.29(0.80) 2= 2.70(0.81)
Number of SB bouts lasting 60-120mins	t(49)=-0.18, p=0.175 1= 1.66(1.07) 2= 1.71(0.85)
Time spent in SB bouts lasting 60-120mins (hrs)	t(49)=-0.16, p=0.189 1= 2.25(1.47) 2= 2.31(1.18)
Number of SB bouts lasting 120mins	U=276,50, p=0.363 1= Md:0.25 (IQR:0.00, 0.29) 2= Md:0.29 (IQR:0.04, 0.43)
Time spent in SB bouts lasting 120mins (hrs)	U=278.00, p=0.381 1= Md:0.58 (IQR:0.00, 0.85) 2= Md:0.74 (IQR:0.08, 1.20)
Anxiety	U=307.00, p=0.742 1= Md:3.00 (IQR:1.00, 4.00) 2= Md:2.00 (IQR:1.00, 3.75)
Anger	U=319.00, p=0.906 1= Md:1.00 (IQR:1.00, 2.00) 2= Md:1.00 (IQR:1.00, 2.00)
Sadness	U=270.50, p=0.284 1= Md:1.00 (IQR:1.00, 3.00) 2= Md:2.00 (IQR:1.00, 3.75)
Irritable	U=289.00, p=0.495 1= 2.00 (IQR:1.00, 4.00) 2= 2.50 (IQR:1.00, 3.75)
Elation	U=265.00, p=0.220 1= Md:1.00 (IQR:1.00, 2.00) 2= Md:2.00 (IQR:1.00, 3.75)
Energetic	U=253.50, p=0.170 1= Md:2.00 (IQR:1.00, 3.00) 2= Md:2.50 (IQR:1.25, 4.00)
Total score for depression (QIDS)	U=223.00, p=0.056 1= Md:6.00 (IQR:3.00, 9.00) 2= Md:10.50 (IQR:5.00, 18.00)

There was a significant difference between ASRM ((hypo)mania) total score and BD type (U=193.50, p=0.011), with participants who have BDII scoring higher on the ASRM (Md=3.00, IQR=1.00, 8.00) overall than participants with BDI (Md=0.00, IQR=0.00, 3.00), indicating people with BDII experienced more (hypo)mania symptoms than those with BDI during their participation in the study.

Age of bipolar disorder illness onset (yrs)

Table 9.10 Chapter five non-significant analyses exploring correlations with age of BD onset (yrs)

PA, SB & mood variables	Correlations with age of BD illness onset (yrs)
Time spent stepping (hrs)	r=-0.265, n=49, p=0.066
Number of steps taken	r=-0.211, n=49, p=0.145
Time spent in MVPA (hrs)	r=-0.141, n=49, p=0.332
Time spent standing (hrs)	r=-0.418** n=49
Time spent in light PA (hrs)	r=-0.366** n=49
Number of SB to upright transitions	r=-0.506*** n=49
Time spent in SB bouts lasting 0-30mins (hrs)	r=-0.278, n=49, p=0.053
Number of SB bouts lasting 60-120mins	r=0.272, n=49, p=0.173
Number of SB bouts lasting 120mins	r=0.110, n=49, p=0.450
Time spent in SB bouts lasting 120mins (hrs)	r=0.059, n=49, p=0.687
Number of SB bouts	-0.499*** n=49
Number of SB bouts lasting 0-30mins	-0.507*** n=49
Number of SB bouts lasting 30-60mins	0.411** n=49
Time spent in SB bouts lasting 30-60mins	0.428** n=49
Time spent in SB bouts lasting 60-120mins (hrs)	0.307** n=49
Anxiety	r=-0.023, n=49, p=0.875
Anger	r=-0.075, n=49, p=0.611
Sadness	r=0.027, n=49, p=0.854
Irritable	r=-0.159, n=49, p=0.276
Elation	r=-0.034, n=49, p=0.819
Energetic	r=-0.019, n=49, p=0.899
Total score for depression (QIDS)	r=-0.189, n=49, p=0.501
Total score for (hypo)mania (ASRM)	r=-0.010, n=49, p=0.945

**p<0.05 **p<0.01, ***p<0.001*

Table 9.10 above shows significant negative associations between age of BD illness onset (yrs) and PA variables time sent standing, time spent in light PA, and the number of sedentary to upright transitions, i.e. participants with a later illness onset spent less time standing, less time in light PA and had fewer sedentary to upright transitions than those with an earlier illness onset. Age of illness onset (yrs) was also negatively associated with the number of sedentary bouts, and the number of sedentary bouts lasting 0-30mins, i.e. participants with a later illness onset had fewer breaks in sedentary time, and fewer short bouts of sedentary time than those with an earlier illness onset. Table 9.10also shows positive associations between age of illness onset (yrs) and the number of sedentary bouts lasting 30-60mins, time spent in sedentary bouts lasting 30-60mins, as well as time spent in sedentary bouts lasting 60-120mins, i.e. participants with a later illness onset spent more time in sedentary bouts lasting over 30mins without a break than those with an earlier illness onset.

Length of bipolar disorder illness (yrs)

Table 9.11 Chapter five non-significant analyses exploring correlations with length of BD illness (yrs)

PA, SB & mood variables	Correlations with length of BD illness (yrs)
Time spent stepping (hrs)	r=0.235, n=49, p=0.104
Number of steps taken	r=0.158, n=49, p=0.278
Time spent in MVPA (hrs)	r=0.145, n=49, p=0.319
Number of SB to upright transitions	r=0.227, n=49, p=0.116
Time spent in SB (hrs)	r=0.000, n=49, p=0.999
Number of SB bouts	r=0.223, n=49, p=0.123
Number of SB bouts lasting 0-30mins	r=0.219, n=49, p=0.131
Time spent in SB bouts lasting 0-30mins (hrs)	r=0.140, n=49, p=0.336
Number of SB bouts lasting 30-60mins	r=-0.246, n=49, p=0.089
Time spent in SB bouts lasting 30-60mins (hrs)	r=-0.229, n=49, p=0.114
Number of SB bouts lasting 60-120mins	r=-0.033, n=49, p=0.821
Time spent in SB bouts lasting 60-120mins (hrs)	r=-0.039, n=49, p=0.792
Number of SB bouts lasting 120mins	r=0.091, n=49, p=0.533
Time spent in SB bouts lasting 120mins (hrs)	r=0.073, n=49, p=0.618
Anxiety	r=-0.002, n=49, p=0.989
Anger	r=0.137, n=49, p=0.137
Sadness	r=0.033, n=49, p=0.819
Irritable	r=0.022, n=49, p=0.881
Elation	r=0.176, n=49, p=0.226
Total score for depression (QIDS)	r=0.035, n=49, p=0.811
Total score for (hypo)mania (ASRM)	r=0.182, n=49, p=0.211

Number of depression episodes (per illness year)

Table 9.12 Chapter five non-significant analyses exploring correlations with num. of depression episodes (per illness year)

PA, SB & mood variables	Correlations with the number of depression episodes (per illness year)
Time spent standing (hrs)	r=-0.124, n=47, p=-0.260
Time spent stepping (hrs)	r=-0.260, n=47, p=0.078
Time spent in light PA (hrs)	r=-0.128, n=47, p=0.390
Number of SB to upright transitions	r=0.011, n=47, p=0.941
Time spent in SB (hrs)	r=0.232, n=47, p=0.117
Number of SB bouts	r=0.013, n=47, p=0.928
Number of SB bouts lasting 0-30mins	r=0.004, n=47, p=0.978
Time spent in SB bouts lasting 0-30mins (hrs)	r=-0.047, n=47, p=0.753
Number of SB bouts lasting 30-60mins	r=0.113, n=47, p=0.448
Time spent in SB bouts lasting 30-60mins (hrs)	r=0.109, n=47, p=0.464
Number of SB bouts lasting 60-120mins	r=0.139, n=47, p=0.350
Time spent in SB bouts lasting 60-120mins (hrs)	r=0.152, n=47, p=0.306
Number of SB bouts lasting 120mins	r=0.100, n=47, p=0.503
Time spent in SB bouts lasting 120mins (hrs)	r=0.148, n=47, p=0.302
Anxiety	r=0.268, n=47, p=0.069
Anger	r=0.065, n=47, p=0.664
Sadness	r=0.250, n=47, p=0.090
Irritable	r=0.210, n=47, p=0.156
Elation	r=-0.019, n=47, p=0.902
Energetic	r=-0.059, n=47, p=-0.694
Total score for depression (QIDS)	r=0.272, n=47, p=0.064
Total score for (hypo)mania (ASRM)	r=0.080, n=47, p=0.594

The number of steps taken was negatively associated with average number of depression episodes (per illness year) (r=-0.314, n=47, p=0.032) only. Time spent in MVPA was also only negatively associated (r=-0.315, n=47, p=0.031) with the number of depression episodes (per illness year).

Number of (hypo)manic episodes (per illness year)

Table 9.13 Chapter five non-significant analyses exploring correlations with num. (hypo)manic episodes (per illness year)

PA, SB & mood variables	Correlations with the number of (hypo)manic episodes (per illness year)
Time spent standing (hrs)	r=-0.040, n=44, p=0.796
Time spent stepping (hrs)	r=-0.180, n=44, p=0.241
Number of steps taken	r=-0.173, n=44, p=0.262
Time spent in light PA (hrs)	r=-0.235, n=44, p=0.125
Time spent in MVPA (hrs)	r=-0.162, n=44, p=0.294
Number of SB to upright transitions	r=-0.087, n=44, p=0.577
Time spent in SB (hrs)	r=0.048, n=44, p=0.756
Number of SB bouts	r=-0.087, n=44, p=0.409
Number of SB bouts lasting 0-30mins	r=-0.067, n=44, p=0.665
Time spent in SB bouts lasting 0-30mins (hrs)	r=-0.128, n=44, p=0.409
Number of SB bouts lasting 30-60mins	r=-0.032, n=44, p=0.836
Time spent in SB bouts lasting 30-60mins (hrs)	r=-0.032, n=44, p=0.838
Number of SB bouts lasting 60-120mins	r=-0.037, n=44, p=0.813
Time spent in SB bouts lasting 60-120mins (hrs)	r=0.010, n=44, p=0.948
Number of SB bouts lasting 120mins	r=-0.035, n=44, p=0.823
Time spent in SB bouts lasting 120mins (hrs)	r=0.025, n=44, p=0.871
Anxiety	r=0.089, n=44, p=0.566
Anger	r=-0.002, n=44, p=0.991
Sadness	r=0.053, n=44, p=0.733
Irritable	r=0.152, n=44, p=0.323
Elation	r=0.283, n=44, p=0.062
Energetic	r=-0.047, n=44, p=0.764
Total score for depression (QIDS)	r=0.194, n=44, p=0.206
Total score for (hypo)mania (ASRM)	r=0.111, n=44, p=0.472

Physical health co-morbidities

Elevated cholesterol

Table 9.14 Chapter five non-significant analyses exploring differences between those with & without a history of elevated cholesterol

PA, SB & mood variables	Differences between those reporting elevated cholesterol & not (y=yes, n=no)
Time spent standing (hrs)	t(44)=-0.97, p=0.482 Y= 4.41(1.40) N= 3.97(1.50)
Time spent stepping (hrs)	t(44)=-1.25, p=0.434 Y= 1.86(0.55) N= 1.61(0.67)
Number of steps taken	t(44)=-0.60, p=0.249 Y= 4173.37(1304.14) N= 3853.96(1888.17)
Time spent in light PA (hrs)	t(44)=-2.02, p=0.534 Y= 0.79(0.30) N= 0.63(0.24)
Time spent in MVPA (hrs)	t(44)=-0.57, p=0.159 Y= 1.07(0.32) N= 0.99(0.52)
Number of SB to upright transitions	t(44)=0.25, p=0.804 Y= 53.46(16.60) N= 54.75(16.38)
Time spent in SB (hrs)	t(44)=-0.20, p=0.351 Y= 9.94(1.88) N= 9.83(1.62)
Number of SB bouts	t(44)=0.25, p=0.351 Y= 53.68(16.61) N= 54.95(16.39)
Number of SB bouts lasting 0-30mins	t(44)=0.24, p=0.967 Y= 48.27(17.30) N= 49.60(17.76)
Time spent in SB bouts lasting 0-30mins (hrs)	t(44)=0.93, p=0.863 Y= 4.33(1.11) N= 4.68(1.26)
Number of SB bouts lasting 30-60mins	t(44)=1.24, p=0.453 Y= 3.19(1.17) N= 3.64(1.15)
Time spent in SB bouts lasting 30-60mins (hrs)	t(44)=1.13, p=0.469 Y= 2.25(0.82) N= 2.53(0.81)
Number of SB bouts lasting 60-120mins	t(44)=-1.60, p=0.699 Y= 1.92(0.95) N= 1.49(0.83)
Time spent in SB bouts lasting 60-120mins (hrs)	t(44)=-1.66, p=0.472 Y= 2.01(1.11) N= 2.63(1.37)
Number of SB bouts lasting 120mins	U=186.50, p=0.209 Y= Md:0.29 (IQR:0.14, 0.43) N= Md:0.15 (IQR: 0.00, 0.36)
Time spent in SB bouts lasting 120mins (hrs)	U=191.00, p=0.253 Y= Md: 0.67 (IQR:0.37, 1.02) N= Md:0.47 (IQR:0.00, 0.94)
Anxiety	U=209.50, p=0.468 Y= Md: 2.50 (IQR:1.25, 4.00) N= Md: 2.00 (IQR:1.00, 3.25)
Anger	U=179.00, p=0.067 Y= Md: 1.00 (IQR:1.00, 2.00) N=Md: 1.00 (IQR:1.00, 1.00)

Sadness	U=220.50, p=0.629 Y= Md: 2.00 (IQR:1.00, 2.00) N=Md: 1.00 (IQR:1.00, 3.00)
Irritable	U=222.00, p=0.666 Y= Md: 2.00 (IQR:1.00, 3.75) N=Md: 2.00 (IQR:1.00, 4.00)
Elation	U=228.50, p=0.773 Y= Md: 1.00 (IQR:1.00, 2.75) N= Md: 1.50 (IQR:1.00, 3.50)
Energetic	U=210.50, p=0.484 Y= Md: 2.50 (IQR:2.00, 3.00) N= Md: 2.00 (IQR:1.00, 4.00)
Total score for depression (QIDS)	U=214.50, p=0.555 Y= Md: 6.50 (IQR:4.25, 17.00) N= Md: 8.00 (IQR:2.75, 14.25)
Total score for (hypo)mania (ASRM)	U=180.00, p=0.153 Y= Md: 2.50 (IQR:1.00, 4.00) N= Md: 0.00 (IQR:0.00, 7.25)

There was a significant difference of those reporting elevated cholesterol or not on time spent in light PA (hrs) (t(44)=2.02, p=0.049) with those reporting high cholesterol spending more time in light PA (hrs) (mean=0.79(0.30)) than those who did not report high cholesterol (mean=0.63(0.24)).

9.17 Appendix Q: Chapter six (study three) additional analyses – identifying confounding factors

Gender

Table 9.15 Chapter six non-significant analyses exploring differences between genders

PA, SB & mood variables	Differences between males and females (m=males f=females)
IPAQ total time spent in vigorous intensity PA (hrs)	U=70117.50, p=0.150 M= Md:0.00 (IQR:0.00, 3.00) F= Md: 0.00 (IQR:0.00, 2.00)
IPAQ total time spent in moderate intensity PA (hrs)	U=71626.00, p=0.380 M= Md: 0.00 (IQR:0.00, 2.00) F= Md: 0.09 (IQR:0.00, 2.37)
IPAQ total time spent walking (hrs)	U=70908.50, p=0.300 M= Md: 3.00 (IQR:1.25, 7.00) F= Md: 3.50 (IQR:1.50, 7.00)
IPAQ total time spent in PA (hrs)	U=73869.50, p=0.914 M= Md: 6.50 (IQR:2.33, 15.00) F= Md: 6.92 (IQR:2.92, 14.06)
MSQ total week sitting time (hrs)	U=39802.50, p=0.355 M= Md: 56.00 (IQR:39.92, 78.00) F= Md: 56.25 (IQR:41.71, 74.83)
Total score for (hypo)mania (ASRM)	U=106106.50, p=0.299 M= Md: 2.00 (IQR:0.00, 5.00) F= Md: 1.00 (IQR:0.00, 4.00)

There was a significant difference between males and females on the total score for depression (BDI-19); with females (Md:11.00, IQR:4.00, 21.00) scoring significantly higher than males (Md:9.00, IQR:3.00, 18.00) (U=98448.50, M=318, F=689, p=0.010).

Age

Table 9.16 Chapter six analyses exploring correlations with age (yrs)

PA, SB & mood variables	Correlations with age
IPAQ total time spent in vigorous intensity PA (hrs)	r=-0.061, n=824, p=0.080
IPAQ total time spent in moderate intensity PA (hrs)	r=-0.023, n=824, p=0.515
IPAQ total time spent walking (hrs)	r=0.042, n=824, p=0.233
IPAQ total time spent in PA (hrs)	r=0.022, n=824, p=0.530
Total week sitting time (hrs) (MSQ)	-0.159*** n=623
Total score for (hypo)mania (ASRM)	r=0.023, n=824, p=0.457
Depression total score (BDI-19)	-0.129*** n=1007

Table 9.16 above shows two significant, negative, small strength associations between the total week sitting time (MSQ) and the total depression score (BDI-19) with age. Table 6.8 in the previous section (page 330) identified no significant associations between the total time spent sitting (MSQ) and the total depression score (BDI-19), and so despite the above significant differences in Table 9.16, the relationship between total week sitting time and total depression score presented

previously (page 330) was not explored further by presenting this relationship in separate age groupings.

Lifetime psychiatric history

Bipolar disorder sub-type

Table 9.17 Chapter six analyses exploring differences between BD sub-type

PA, SB & mood variables	Differences between BDI & BDII (1=BDI, 2=BDII)
Total weekday sitting time (hrs) (MSQ)	U=52631.50* 1=489 Md=55.00 (IQR: 37.92, 74.17) 2=240 Md=58.50 (IQR: 43.27, 77.27)
IPAQ total time spent walking (hrs)	U=74525.00, p=0.733 1= Md: 3.50 (IQR:1.50, 7.00) 2= Md: 3.50 (IQR:1.00, 7.50)
IPAQ total time spent in PA (hrs)	U=71725.00, p=0.226 1= Md: 6.50 (IQR:2.67, 12.63) 2= Md: 7.00 (IQR:3.00, 17.50)
Total score for (hypo)mania (ASRM)	U=111118.50, p=0.945 1= Md: 1.00 (IQR:0.00, 4.00) 2= Md: 2.00 (IQR:0.00, 5.00)

**p<0.05, **p<0.01, ***p<0.001*

Table 6.8 in chapter six (page 330) identified no significant associations between the total week sitting time (MSQ) and the total depression score (BDI-19), and so despite the significant difference between those with BDI and BDII on their total depression score (BDI-19) and total week sitting time in Table 9.17 above, the relationship between total week sitting time and total depression score presented previously (page 330) was not explored further by presenting this relationship in separately by BD sub-type.

Age of bipolar disorder illness onset (yrs)

Table 9.18 Chapter six non-significant analyses exploring correlations with age of BD illness onset (yrs)

PA, SB & mood variables	Correlations with age of BD illness onset (yrs)
IPAQ total time spent in vigorous intensity PA (hrs)	r=0.009, n=798, p=0.808
IPAQ total time spent in moderate intensity PA (hrs)	r=0.020, n=798, p=0.568
IPAQ total time spent walking (hrs)	r=-0.005, n=798, p=0.890
IPAQ total time spent in PA (hrs)	r=0.026, n=798, p=0.461
MSQ total week sitting time (hrs)	r=-0.019, n=603, p=0.639
Total score for (hypo)mania (ASRM)	r=-0.005, n=979, p=0.876

Age of BD illness onset (yrs) was significantly negatively associated with the total score for depression (BDI-19) (r=-0.181, n=972, p<0.001). This association was small in strength.

Length of bipolar disorder illness (yrs)

Table 9.19 Chapter six non-significant analyses exploring correlations with length of BD illness (yrs)

PA, SB & mood variables	Correlations with length of BD illness (yrs)
IPAQ total time spent in vigorous intensity PA (hrs)	r=-0.058, n=798, p=0.102
IPAQ total time spent in moderate intensity PA (hrs)	r=-0.036, n=798, p=0.310
IPAQ total time spent walking (hrs)	r=0.038, n=798, p=0.277
IPAQ total time spent in PA (hrs)	r=0.003, n=798, p=0.927
Total score for depression (BDI-19)	r=0.018, n=972, p=0.572
Total score for (hypo)mania (ASRM)	r=0.026, n=979, p=0.423

Length of BD illness (yrs) was significantly negatively associated with the total time spent sitting (MSQ) (r=-0.155, n=603, p<0.001). This association was small in strength.

Number of depression episodes (per illness year)

Table 9.20 Chapter six non-significant analyses exploring correlations with num. depression episodes (per illness year)

PA, SB & mood variables	Correlations with number of depression episodes (per illness year)
IPAQ total time spent in vigorous intensity PA (hrs)	r=-0.037, n=737, p=0.321
IPAQ total time spent in moderate intensity PA (hrs)	r=0.029, n=737, p=0.435
IPAQ total time spent walking (hrs)	r=-0.015, n=737, p=0.683
IPAQ total time spent in PA (hrs)	r=-0.023, n=737, p=0.526
MSQ total week sitting time (hrs)	r=0.082, n=557, p=0.054
Total score for (hypo)mania (ASRM)	r=0.000, n=900, p=0.990

Number of depression episodes (per illness year) was significantly positively associated with the total score for depression (BDI-19) (r=0.023, n=911, p<0.001). This association was small in strength.

Number of (hypo)manic episodes (per illness year)

Table 9.21 Chapter six analyses exploring correlations with num. (hypo)manic episodes (per illness year)

PA, SB & mood variables	Correlations with number of (hypo)manic episodes (per illness year)
IPAQ total time spent in vigorous intensity PA (hrs)	r=-0.045, n=747, p=0.220
IPAQ total time spent in moderate intensity PA (hrs)	r=0.010, n=747 p=0.793
IPAQ total time spent walking (hrs)	r=-0.036, n=747, p=0.326
IPAQ total time spent in PA (hrs)	r=-0.035, n=747, p=0.337
Total week sitting time (hrs) (MSQ)	0.092* n=563
Total score for (hypo)mania (ASRM)	r=0.058, n=916, p=0.079
Depression total score (BDI-19)	0.159*** n=911

**p<0.05, **p<0.01, ***p<0.001*

Table 9.21 above shows two significant small strength positive associations between total week sitting time (MSQ) and total depression score (BDI-19) with the number of (hypo)manic episodes (per illness year). Table 6.8 in chapter six (page 330) identified no significant associations between the total time spent sitting (MSQ) and the total depression score (BDI-19), and so despite the above significant associations in Table 9.21, the relationship between total week sitting time and total depression score was not explored separately by the number of (hypo)manic episodes (per illness year).

Physical health comorbidities

Elevated cholesterol

Table 9.22 Chapter six non-significant analyses exploring differences between those with & without a history of elevated cholesterol

PA, SB & mood variables	Differences between those with and without a history of elevated cholesterol (y=yes, n=no)
IPAQ total time spent in vigorous intensity PA (hrs)	U=52898.50, p=0.329 Y= Md: 0.00 (IQR:0.00, 2.50) N= Md: 0.00 (IQR:0.00, 2.50)
IPAQ total time spent in moderate intensity PA (hrs)	U=54914.50, p=0.916 Y= Md: 0.00 (IQR:0.00, 2.00) N= Md: 0.00 (IQR:0.00, 2.00)
IPAQ total time spent walking (hrs)	U=54625.50, p=0.834 Y= Md: 4.00 (IQR:1.50, 7.50) N= Md: 3.50 (IQR:1.50, 7.38)
IPAQ total time spent in PA (hrs)	U=55150.00, p=0.995 Y= Md: 7.00 (IQR:2.92, 15.00) N= Md: 6.50 (IQR:3.00, 14.00)
MSQ total week sitting time (hrs)	U=31948.00, p=0.666 Y= Md: 57.00 (IQR:42.00, 74.17) N= Md: 56.00 (IQR:40.21, 76.75)
Total score for (hypo)mania (ASRM)	U=82076.50, p=0.469 Y= Md: 2.00 (IQR:0.00, 5.00) N= Md: 1.50 (IQR:0.00, 4.00)

Participants with a history of elevated cholesterol (Md=11.00, IQR:5.00, 21.00) had a significantly higher total score for depression (BDI-19) than those without (Md=10, IQR:4.00, 19.75) (U=75841.00, y=264, n=632, p=0.032).

Migraines

Table 9.23 Chapter six non-significant analyses exploring differences between those with & without a history of migraines

PA, SB & mood variables	Differences between those with and without a history of migraines (y=yes, n=no)
IPAQ total time spent in vigorous intensity PA (hrs)	U=51188.50, p=0.528 Y= Md: 0.00 (IQR:0.00, 2.71) N= Md: 0.00 (IQR:0.00, 2.25)
IPAQ total time spent in moderate intensity PA (hrs)	U=51866.00, p=0.747 Y= Md: 0.00 (IQR:0.00, 3.00) N= Md: 0.17 (IQR:0.00, 2.00)
IPAQ total time spent walking (hrs)	U=50222.00, p=343 Y= Md: 3.50 (IQR:1.50, 9.50) N= Md: 3.50 (IQR:1.50, 7.00)
IPAQ total time spent in PA (hrs)	U=51009.50, p=0.524 Y= Md:7.00 (IQR:3.00, 17.75) N= Md: 6.58 (IQR:2.96, 14.00)
MSQ total week sitting time (hrs)	U=27821.00, p=0.096 Y= Md: 61.00 (IQR:46.00, 79.00) N= Md: 55.58 (IQR:40.50, 74.25)
Total score for (hypo)mania (ASRM)	U=75045.00, p=0.151 Y= Md: 2.00 (IQR:0.00, 5.00) N= Md: 2.00 (IQR:0.00, 4.00)

Participants with a history of migraines had a significantly higher total score for depression (Md=15.00, IQR:6.00, 24.50) than those without (Md=9.00, IQR:3.00, 17.50) (U=60589.50 y=241 n=657, p<0.001).

Asthma

Table 9.24 Chapter six non-significant analyses exploring differences between those with & without a history of asthma

PA, SB & mood variables	Differences between those with &without a history of asthma (y=yes, n=no)
IPAQ total time spent in vigorous intensity PA (hrs)	U=45559.00, p=0.314 Y= Md: 0.00 (IQR:0.00, 1.75) N= Md: 0.00 (IQR:0.00, 2.50)
IPAQ total time spent in moderate intensity PA (hrs)	U=45914.00, p=0.415 Y= Md: 0.00 (IQR:0.00, 2.75) N= Md: 0.00 (IQR:0.00, 2.00)
IPAQ total time spent walking (hrs)	U=46047.50, p=0.484 Y= Md: 3.50 (IQR:1.67, 7.25) N= Md: 3.50 (IQR:1.33, 7.38)
IPAQ total time spent in PA (hrs)	U=44893.50, p=0.283 Y= Md: 6.00 (IQR:3.00, 14.67) N= Md: 7.00 (IQR:2.85, 14.19)
MSQ total week sitting time (hrs)	U=23835.50, p=0.074 Y= Md: 64.58 (IQR:43.14, 78.00) N= Md: 55.54 (IQR:40.63, 72.40)
Total score for (hypo)mania (ASRM)	U=67838.50, p=0.157 Y= Md: 2.00 (IQR:0.00, 4.00) N= Md: 2.00 (IQR:0.00, 5.00)

Participants with a history of asthma also had a significantly higher total score for depression (Md=13.00, IQR:6.00, 24.00) than those without (Md=9.00 IQR:3.00, 19.00) (U=50608.50 y=209 n=682, p<0.001).

Hypertension

Table 9.25 Chapter six non-significant analyses exploring differences between those with & without a history of hypertension

PA, SB & mood variables	Differences between those with and without a history of hypertension (y=yes, n=no)
IPAQ total time spent in moderate intensity PA (hrs)	U=44010.00, p=0.078 Y= Md: 0.00 (IQR:0.00, 2.00) N= Md: 0.33 (IQR:0.00, 2.00)
IPAQ total time spent walking (hrs)	U=44065.00, p=0.107 Y= Md: 3.50 (IQR:1.00, 7.00) N= Md: 3.50 (IQR:1.50, 7.50)
MSQ total week sitting time (hrs)	U=26288.50, p=0.338 Y= Md: 57.25 (IQR:39.80, 74.34) N= Md: 56.00 (IQR:42.00, 76.75)
Total score for (hypo)mania (ASRM)	U=71203.00, p=0.378 Y= Md: 2.00 (IQR:0.00, 5.00) N= Md: 1.00 (IQR:0.00, 4.00)

9.18 Appendix R: Chapter six (study three) additional comments from participants regarding the International Physical Activity Questionnaire & Marshall Sitting Questionnaire

‘‘I work an irregular pattern and have two part time jobs, both very different as one I sit down most of the day and the other I stand all day and move around. Also they have very different commutes as one I cycle the whole way (25mins each way) the other I part cycle then have a long bus journey’’

‘‘I found the Marshall Sitting Questionnaire very difficult to complete’’

‘‘With regard to the questions about sitting and walking, I cannot give an accurate reply as my days vary greatly depending on my mood, physical health and where I am working.’’

‘‘I have spent a little more time sitting than usual in the past week as I'm working to submit a PhD proposal. I found the physical exercise questions quite difficult to answer.’’

‘‘I don't sit much as this is quite painful but have to lay down to relax’’

‘‘I do not take any medication at all but I Exercise 4 times a week. And Find this is the best type of medication for me.’’

‘‘This questionnaire does not take into account physical disabilities, disorders or impairments, that impact physical activity and ability to do physical activities.’’

‘‘Found it hard to complete. Thought I would mention that recently I broke my ankle about 5 months ago and still off work so have been thinking about that a lot as can't walk properly’’

9.19 Appendix S: Researcher's background, motivations & reflections

Motivations for undertaking this PhD

I found the dissertation component of my honours degree the most enjoyable aspect of my undergraduate studies which motivated me to continue in research and complete a masters by research degree. During this time, I held several part time and voluntary roles in third sector organisations who supported people living with drug and/or alcohol addiction, and mental health difficulties. I realised that although I enjoyed this work, and I really enjoyed working directly with people, I wanted to understand more about the evidence for mental health treatments through my own original research and contribute to the knowledge and evidence base of mental health in general. My previous work and research experience therefore motivated me to continue in research and develop further skills by pursuing a PhD opportunity. It felt like the natural next step in my career and when I saw the studentship advert for this PhD I was excited by the idea of combining an area I was already passionate about, mental health research, and of learning more about bipolar disorder in particular due to the unique symptomology. In terms of physical activity and sedentary behaviour, these were topics I was interested in but did not have much prior knowledge of, and so I felt this PhD gave me the perfect opportunity to learn more about something I would not have otherwise had the chance to.

Previous work experience and skills development

Whilst searching for a suitable PhD opportunity I was working for the Scottish Association of Mental Health as a mental health keyworker in Dundee, Scotland. In this role I worked with people living with severe mental illnesses, mostly schizophrenia, and supported them to work towards recovery-focussed goals. Just prior to this role, I was working on my masters by research thesis exploring criminal behaviours associated with drug use. This was a mixed methods research project where I interviewed ten people living with a heroin addiction who were accessing a needle exchange and harm reduction centre in Dundee, where I was also working part-time whilst studying. During this time, I reflected on a forensic psychology module I had completed as part of my undergraduate degree (BSc Forensic Psychobiology) which taught interview skills for interviewing vulnerable groups, with a focus on non-leading questioning. The module lead, a forensic psychologist, was also a supervisor on my masters by research project who helped me devise a suitable topic guide and practice interview skills such as building rapport, managing silences, using non-leading questions, and how to navigate sensitive topic areas such as drug addiction and criminal behaviour in an interview. This experience was helpful for carrying out the interviews in this PhD research, as I was able to reflect on my experiences of interviewing people living with a mental illness on their personal experiences and how that illness impacted them. I was also aware of the importance of building rapport with participants before asking them anything too personal, offering them choice (e.g., telephone or home visit, time of day, where to sit etc.) being non-judgemental and listening without being too reactive (e.g., nodding to show listening, repeating back what was said for clarification, and not showing strong

emotions such as shock or disgust) to help participants trust me and feel comfortable sharing information with me.

Reflections on carrying out this PhD

I learned the most about bipolar disorder when speaking to people living with bipolar disorder about their experiences and perceptions. Prior to undertaking this PhD, I had a number of assumptions that were challenged early on in the research. For example, I was not aware of the average length of depressive or manic episodes for a diagnosis of bipolar disorder, or that there were different sub-types of bipolar disorder. I was also not aware of the negative impact of (hypo)mania, and that (hypo)mania did not necessarily equate to happiness, which relates to a common misconception people have about bipolar disorder being simply ‘up and down mood’ or ‘happy one minute and sad the next’. In truth I learnt early on that bipolar disorder was much more complex, and that rapid cycling bipolar disorder was not actually a particularly common diagnosis. Carrying out the literature review and interviewing people living with bipolar disorder helped me gain a much better understanding of the real-life presentation and implications of the illness. I gained a deeper appreciation of the complexity of symptoms and developed an interest to know more, as I found that everyone’s experiences of the illness and how it affected their lives were greatly varied, although the perception of always trying to ‘maintain balance’ was evident across the interviewed particpants, how each person managed that was different. Further, prior to undertaking this PhD I assumed that physical activity was always a positive and helpful tool for managing mood and general wellbeing due to common public health messaging on physical activity for mental health. The Wright et al. (2012) paper was the first thing to challenge this assumption, and then again through listening to participants experience. Having recognised these assumptions in myself, I felt I was better placed to then reflect on my themes and ensure I wasn’t simply reporting what I expected to interpret from the data, but what could actually be interpreted from the data.