Technical Note

The development and evaluation of a novel repurposing of a peripheral gaming device for the acquisition of forces applied to a hydraulic treatment plinth.

Abstract

This technical note details the stages taken to create an instrumented hydraulic treatment plinth for the measurement of applied forces in the vertical axis. The modification used a widely available low-cost peripheral gaming device and required only basic construction and computer skills. The instrumented treatment plinth was validated against a laboratory grade force platform across a range of applied masses from 0.5–15 kg, mock Gr I-IV vertebral mobilisations and a dynamic response test. Intraclass correlation coefficients demonstrated poor reliability (0.46) for low masses of 0.5 kg improving to excellent for larger masses up to15 kg respectively; excellent to good reliability (0.97-0.86) for the mock mobilisations and moderate reliability (0.51) for the dynamic response test. The study demonstrates how a cheap peripheral gaming device can be repurposed so that forces applied to a hydraulic treatment plinth can be collected reliably when applied in a clinically reasoned manner.

Keywords: Instrumented Hydraulic Treatment Plinth, Force Data, Manual Therapy

Introduction

The measurement of force has an almost limitless range of applications within Manual Therapy across mobilisation and soft tissue techniques; however the ability to measure forces in specific and relevant situations poses numerous challenges. The authors were interested in creating an instrumented hydraulic treatment plinth for a variety of purposes within this context.

A multitude of studies have documented how feedback is beneficial in the development of students manual therapy skills and for evaluating practice (Gagnon et al., 2016, 2012; Louw et al., 2004; Snodgrass et al., 2015; Suzanne J. Snodgrass et al., 2010; Snodgrass and Odelli, 2012). It is anticipated that the device will be used for research as well as Learning & Teaching purposes, as Snodgrass et al., (2015) details that avenues for distributing their feedback system are being explored, to encourage a wider use of feedback in manual therapy training. There are also, other areas of manual therapy that are yet to be quantified and it is anticipated that, the development of this resource will enable the collection of data for under-researched areas such as soft-tissue massage.

Whilst some instrumented treatment plinths have been cited in literature (Chiradejnant et al., 2001; Snodgrass et al., 2008) they typically involve a complex arrangement of force transducers (at substantial cost) and generally require the ability to write computer code. Although some alternates including mounting a treatment plinth on force platforms, using force mats or pressure sensors (Gagnon et al., 2016; Shannon et al., 2009; Tuttle, 2011) have been proposed as viable alternatives, the concept of an instrumented treatment plinth removes a number of additional variables (mounting on force platforms or multiple sensors) and is therefore entirely preferable for safety and accuracy reasons. The authors therefore aimed to create a low-cost replicable-instrumented hydraulic treatment plinth with commonly accessible materials and methods of data acquisition.

Methods

The lead author had previous experience with the peripheral gaming device (PGD) (Wii Balance Board, Nintendo Inc., Japan) cited to be comparable to a laboratory grade force platform (FP) with the limitation that it is only able to collect force data in a single axis, by design intended to be ground reaction force in the vertical-axis (Clark et al. 2010; Bartlett et al. 2014). The PGD uses four strain-gauge transducers to measure force applied to each corner of a rigid board and transmits data wirelessly to a host console or computer. A major attraction of the PGD is that it is widely available at a fraction of the cost of a laboratory grade FP (Bartlett et al., 2014; Clark et al., 2010). PGDs can be found from as little as £6 UKP compared to several thousand UKP for a laboratory FP. The internal construction (Figure 1) of a PGD provided inspiration for the repurposing of the PGD internals from its manufactured frame onto a bespoke steel frame.

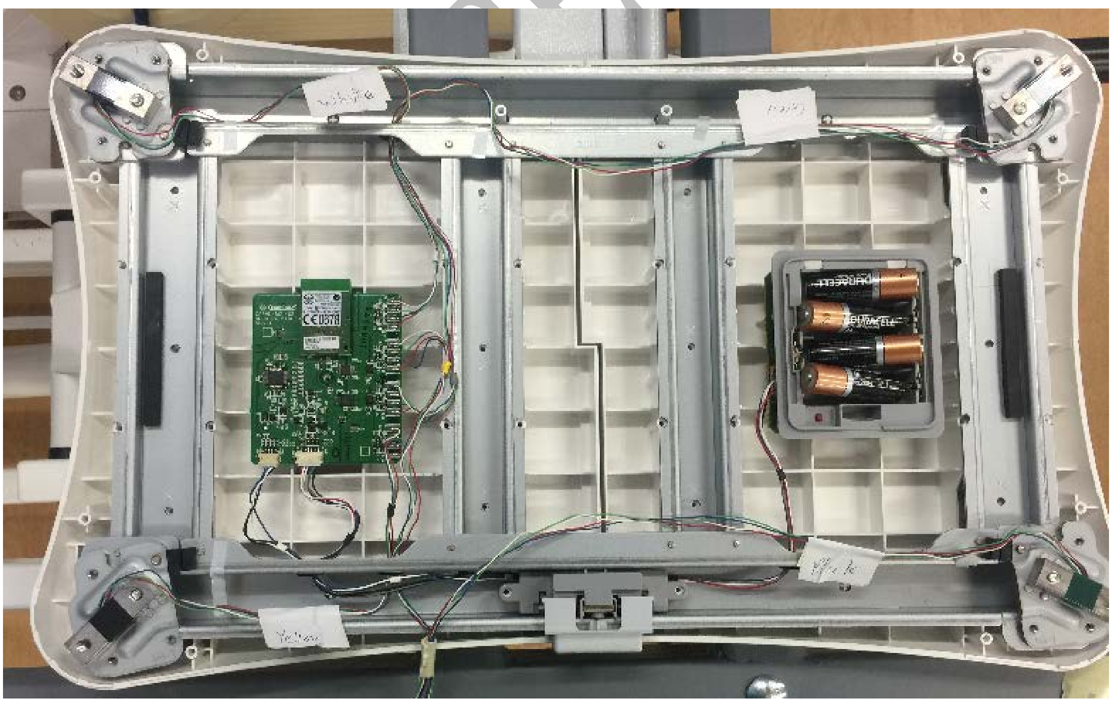

Figure 1: Internals of a Wii Balance Board

Integration of the PGD transducers into a treatment plinth required separation and isolation of the top cushioned patient sections from the lower base-frame.

A standard two-section treatment plinth (white frame in figure 2) was deconstructed to enable the fabrication of two steel frames (grey frame in figure 2) from 40 mm box section steel. This provided a complete rigid body for the force transducers that were sandwiched below the padded sections of the treatment plinth for the patient and ensured that a minimal unloaded mass was placed onto the force transducers so that their working range would not be exceeded. The padded cushion sections were mounted on plywood and therefore not suitable to mount onto the force transducers directly.

Figure 2: Original two-section treatment plinth base-frame (white) and one fabricated steel frame (grey).

The internal force transducers of the PGD together with associated wiring and electronics were noted then carefully removed from the plastic board housing to enable their layout and locations to be up scaled to the much larger dimensions of the hydraulic treatment plinth. Each force transducer was mounted (bolted above and below) with the appropriate plates (figure 3) from the PGD enabling specific deformation of the load cell as the manufacturers had intended and then rewired to complete and extend the circuits. Once the padded sections of the treatment plinth had been bolted into place, and the new sub-frames bolted to the original base-frame, the treatment plinth was rigid (in all directions and under normal loading) and able to function safely as before but with the ability to collect force data in the vertical axis, all at a cost of less than £400 to create the PGD_Plinth.

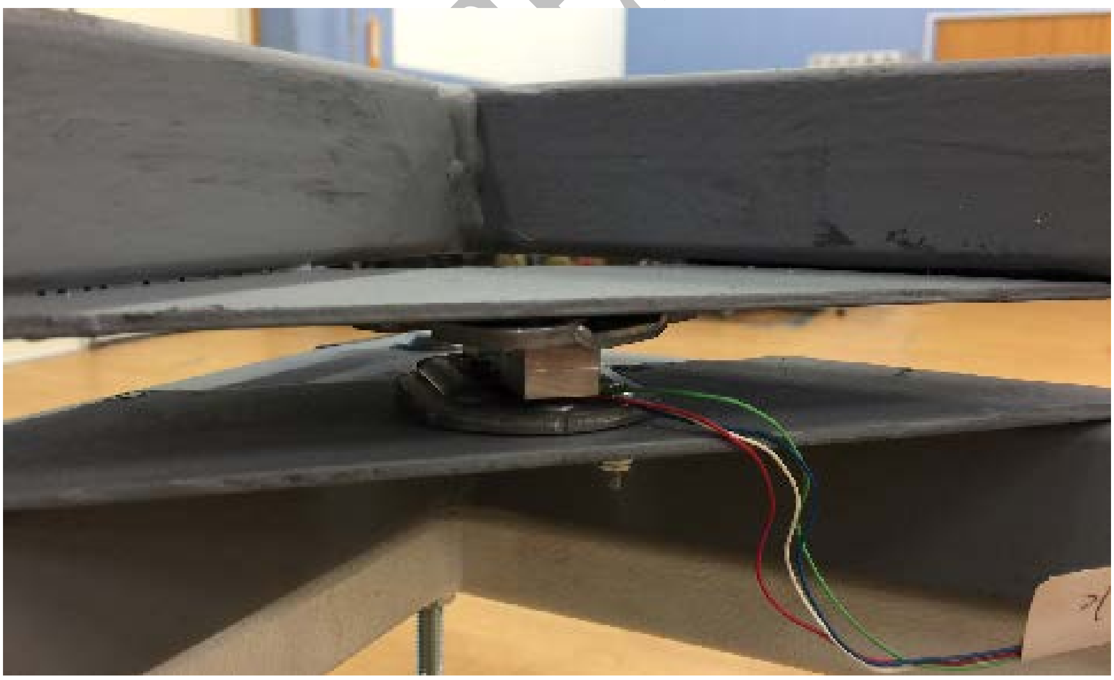

Figure 3: A PGD force transducer between the two steel frames (prior to being bolted into place).

Validation

Forceplates (FP) are known as the gold standard of force measurement in a laboratory setting, as a result the PGD_Plinth was positioned across two floor-mounted FP's (AMTI Plates, Watertown, USA) and a range of known masses and mock mobilisation grades applied to establish the accuracy of the PGD_Plinth.

As the PGD_Plinth is intended to record forces applied to a subject, an 80 kg mass was applied to the treatment plinth to simulate the presence of a subject for the three trials:

Trial 1: Eight smaller incremental loads were then added (0.5, 1, 1.25, 2.5, 5, 7.5, 10 and 15 kg plates) on and off five times each to simulate effleurage strokes being applied.

Trial 2: Mock mobilsation grades (I-IV) were then applied to the 80kg mass by an experienced clinical therapist 20 times per grade, without any feedback to simulate how vertebral mobilisations would be clinically applied to a patient.

Trial 3: A 2kg medicine ball was dropped onto the treatment plinth at varying heights fifteen times to assess the dynamic response of the PGD_Plinth.

Data Collection

The PGD wirelessly transmits data via Bluetooth, an aspect that has been utilised by many authors when applying the PGD to a variety of other applications. The Wii Balance Board Project (Ahmed, 2016) is a freely available set of files (CU_WiiBB) for acquiring raw data from the PGD in real time with the use of Matlab (The Mathworks, USA) through a Bluetooth enabled, Windows computer (Microsoft, USA). The Matlab code required a minor modification to the original calibration procedures due to the weight of the steel frame and treatment plinth padding being considerably greater than the top of a standard PGD (changing the initial start value to offset the additional weight of the steel frame).

Data Analysis

PGDs demonstrate variable sampling frequencies with rates between 30 and 100 Hz cited (Audiffren and Contal 2016). With the PGD_Plinth raw data was observed at approximately 30Hz through Matlab and processed into a .txt file. To enable a comparison of the force plots, data from the PGD_Plinth (~30Hz) was interpolated to a fixed frequency of 30 Hz.

Raw data from the FP's were collected at 60 Hz and processed into a .csv file in Vicon Workstation (Oxford, UK). The FP data were also down-sampled from 60Hz to 30Hz enable an appropriate comparison.

Following interpolation, FP data were filtered with a 5Hz low pass, 4th order, Butterworth Filter (Bioware, Kistler Holding AG, Czech Republic) to remove high frequency noise components arising from natural resonances in the treatment plinth structure.

All of the data were imported into Excel (Microsoft, USA) to enable the summation of total force from the two FP's and the total force from all four force transducers from the PGD_Plinth for comparison. The two respective totals (FP and PGD_Plinth) were aligned and the following sample was taken and analysed using the procedures described below from each of the three trials.

Trial 1: the force curves from the loading and unloading of each plate across the five repetitions were isolated for comparison in their entirety with the use of Intraclass Correlations Coefficients (ICC's) calculated in SPSS (IBM, USA).

Trial 2: the force curves from each of the 20 mobilisations were isolated and a macro-enabled spreadsheet calculated the peaks and troughs of the mobilisations producing mean, standard deviation and 95% confidence intervals for the peak and amplitude forces. ICC's were also calculated using the same procedure as above for each grade.

Trial 3: the force curves from the fifteen impacts were isolated in their entirety and ICC's were calculated as above.

Results

Trial 1

The single measure ICC values in Table 2 show that the PGD_Plinth was able to measure forces in the vertical axis; 'poorly' when the mass was less than and just over 0.5kg (4.9N), 'moderately' when the mass was around 1 kg (9.8 N), 'good' when the mass was just under 1.25 to just over 2.5kg (12.3-24.5N) and 'excellently' when the mass was over 5kg (49.1N) based on the ICC interpretation guidelines from Koo and Li (2016).

Table 2: ICC values from each of the loads (Kg) applied

		95% Confidence Intervals			
Weight (Kg)	ICC	Lower	Upper	df	Sig.
0.5	0.46	0.41	0.50	1200	<0.001
1	0.68	0.64	0.71	945	<0.001
1.25	0.78	0.76	0.81	964	<0.001
2.5	0.90	0.88	0.91	1182	<0.001
5	0.96	0.95	0.96	858	<0.001
7.5	0.97	0.97	0.98	928	<0.001
10	0.99	0.99	0.99	835	<0.001
15	1.00	1.00	1.00	820	<0.001

Trial 2

Figure 5 provides an example of the visual congruence between the mock mobilisations at Grade IV between the devices, half of the dataset is plotted to enable appropriate detail to be conveyed. From the four grades of mobilisations applied, three of them had ‘excellent’ reliability with ICC’s comfortably greater than 0.9. The grade I mock mobilisations were comparable with an ICC value at the upper most end of the ‘good’ reliability category (Table 3).

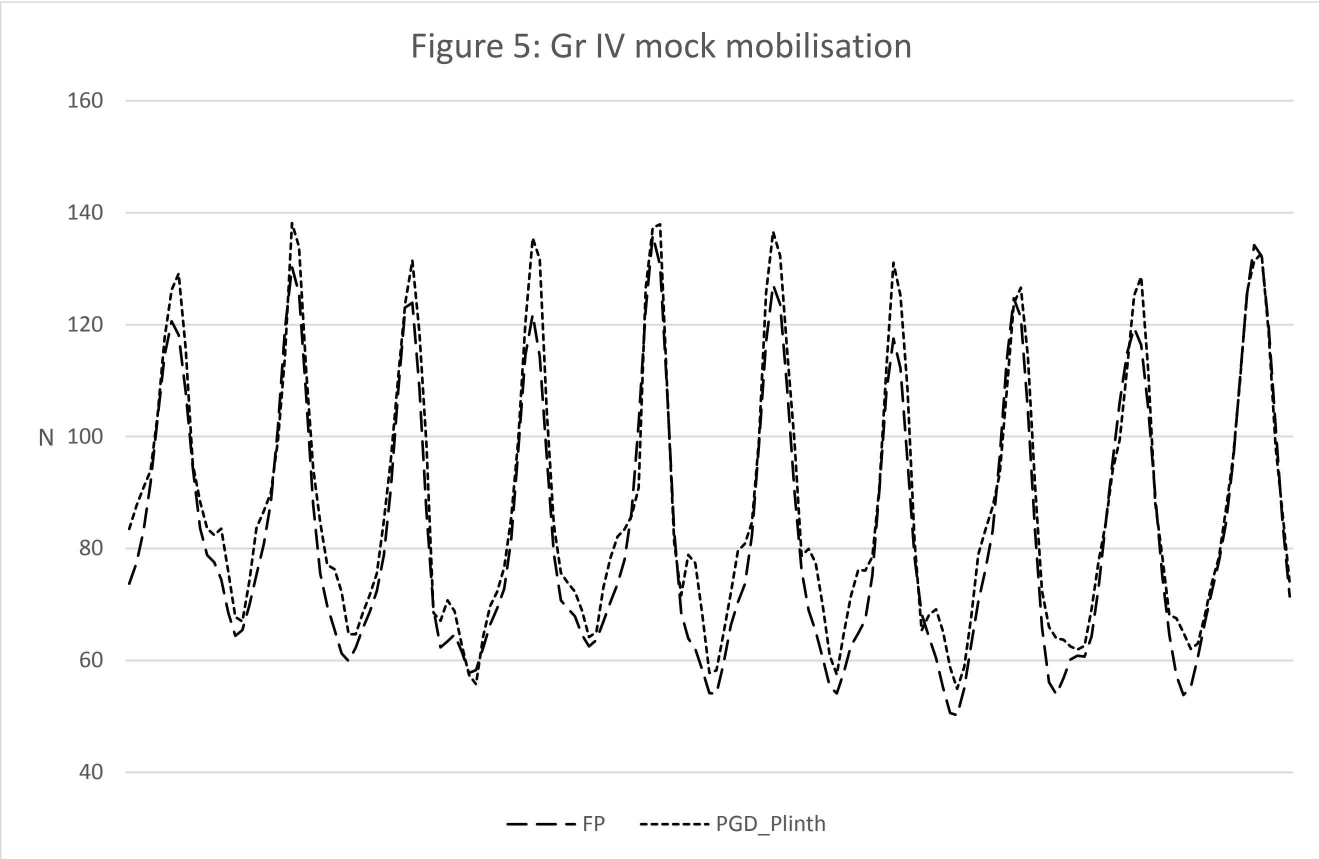

Table 3: ICC values from each of the mock mobilisation grades

		95% Confidence Intervals			
	ICC	Lower	Upper	df	Sig.
Gr I	0.86	0.88	0.82	323	<0.001
Gr II	0.92	0.94	0.91	341	<0.001
Gr III	0.98	0.98	0.97	344	<0.001
Gr IV	0.97	0.98	0.97	363	<0.001

The peak forces applied (Table 4) are highly comparable between devices as are the amplitude forces (Table 5). However, the PGD_Plinth is reporting higher peak values for all grades but only two of the four grades are reported as higher for the amplitude forces. The SD’s are of similiar magnitudes and the 95% confidence intervals have a high degree of overlap reinforcing the ICC values obtained.

Table 4: Peak forces for mock vertebral mobilisations across Grades I-IV

		Mean Peak (N)	SD Peak (N)	95% Confidence Intervals Lower	Upper
Gr I	FP	32.25	8.03	28.73	35.77
	PGD_Plinth	33.87	8.43	30.18	37.57
Gr II	FP	50.37	5.29	48.05	52.68
	PGD_Plinth	54.00	5.09	51.77	56.23
Gr III	FP	83.31	7.42	80.06	86.56
	PGD_Plinth	88.73	8.50	85.01	92.46
Gr IV	FP	128.41	9.17	124.49	132.34
	PGD_Plinth	135.25	10.85	130.61	139.89

Table 5: Amplitude forces for mock vertebral mobilisations across Grades I-IV

		Mean Amplitude (N)	SD Amplitude (N)	95% Confidence Intervals Lower	Upper
Gr I	FP	14.45	4.01	10.99	17.91
	PGD_Plinth	12.65	2.70	11.43	13.86
Gr II	FP	29.21	6.02	26.50	31.92
	PGD_Plinth	27.93	5.98	25.24	30.61
Gr III	FP	45.24	9.43	41.00	49.48
	PGD_Plinth	47.06	9.46	42.81	51.31
Gr IV	FP	65.83	8.70	62.02	69.65
	PGD_Plinth	68.19	8.91	64.28	72.09

Trial 3

The data (Table 6) from the dynamic response trial ICC indicates that there is only a 'moderate' reliability between the two devices when a 2 kg ball is dropped onto them from varying heights.

Table 6: ICC values from the 2 kg ball dynamic response test

		95% Confidence Intervals			
	ICC	Lower	Upper	df	Sig.
2kg Ball	0.51	0.46	0.55	1063	<0.001

Discussion

The findings of this paper indicate that it is possible to repurpose a peripheral gaming device to acquire relatively accurate and reliable force measurement data in the vertical axis from a hydraulic treatment plinth with simple modifications for a range of applications. Trial 1 was designed to simulate effleurage strokes being applied of varying pressure to a mock subject with a mass of 80 kg. Whilst the ICC's for masses less than ~1.25 kg were only moderate to poor, it showed the PGD_Plinth is sensitive enough to detect this small magnitude of change even when preloaded with a substantial mass. Contextually, loads less than ~1.25kg equate to very small forces in massage strokes and as such are not overly relevant for this modality. As soon as the masses exceed ~1.25kg they were good and then excellent above ~5kg, these are more representative of the forces likely to be experienced during a massage and as such the PGD_Plinth is able to provide good to excellent force data with a high degree of precision. Trial 2 also used the mock subject with a mass of 80kg to which mock mobilisation (mock, as there was no feedback relating to stiffness and movement as there would be during a real vertebral mobilisation). The findings from this trial were particularly encouraging as the PGD_Plinth was able to measure all grades reliably with ICC's approaching or exceeding the 0.9 value deemed to show 'excellent' reliability (Koo and Li, 2016). Given the findings above it is of no surprise that the grade I mobilisations were the least reliable of the four sets due to the smaller forces involved. The peak and amplitude forces are highly comparable with the FP despite being consistently greater in magnitude than those collected by the FP. Whilst this is not entirely ideal from a research perspective in a practical setting this may only affect efficacy of the vertebral pressure and will ensure that no mobilisation is too forceful. The peak and amplitude forces measured were typically lower than those cited by Snodgrass et al. (2010) for each grade however, the SD's cited by the author encompass the values measured by this paper demonstrating that there is overlap and that the values are comparable.

Trial 3 was designed to assess the dynamic response of the treatment plinth to high speed loading and unloading, again the treatment plinth was preloaded with the mock subject. The findings highlight a moderate reliability between the two devices indicating that the PGD_Plinth may not be best suited for measuring high speed dynamic forces such as those encountered during tapotement strokes. Factors that compound this will be due to the low sampling frequency, the treatment plinths padding which has been shown previously to confound measurements (Maher et al., 1999) and the concertina treatment plinth structure that will natural absorb some of the forces as well. Referring back to the treatment plinth padding, compressing the padding with the mock subject would have potentially reduced its influence on the forces measured consistently across the trials.

The hydraulic treatment plinth will be utilised to acquire data from manual therapy techniques that are traditionally applied in the vertical axis. Typically, this could include Anterior-Posterior or Posterior-Anterior mobilisations to peripheral joints when the patient is supine or prone, Posterior-Anterior vertebral mobilisations or for effleurage massage techniques applied in the Vertical axis. Whilst the PGD_Plinth has limitations by only collecting data in one axis, it is possible to calculate other values given other known parameters. For example, centre-of-pressure could be calculated if the *x* and *y* co-ordinates were known for each of the transducers pressure, however the validity would need to be confirmed. As a result there are a range of other potential applications for the PGD_Plinth that are as yet unknown within a manual therapy context.

Conclusion

Overall the findings of this technical note provide evidence that a peripheral gaming device can be appropriately repurposed to instrument a hydraulic treatment plinth to collect valid force data in the vertical axis in a manual therapy setting where forces are applied in a clinically reasoned manner. This setup provides an effective solution for collecting force data with widely available materials and software at minimal cost for a variety of Manual Therapy applications.

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