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Original Article

The effectiveness of a practical half-time re-warm-up strategy in youth female basketball players

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Abstract:
Problem Statement: Passive rest during basketball games could reduce athletes' performance and increase the risk of injury during the second half of the game due to loss of muscle temperature. **Approach:** The re-warm-up activities during half-time could help avoid this problem, but there is a lack of research on their efficacy, especially in basketball. **Purpose:** This study aimed to assess the influence of two half-time re-warm-up strategies (that do not demand additional equipment) on measures of performance and the physical, sports and perceptual response during a basketball simulated match. **Methods:** Ten female basketball players U16 completed a traditional intervention and alternative strategy based on bouncing, in which participants completed two 40-minute games (4 x 10-minute periods with a 10-minute half-time interspersing the third and fourth periods) separated by four days. The traditional trial comprised a passive 6-minute period followed by 3 minutes of shooting wheel, whilst the alternative trial comprised a passive 6-minute period, followed by 1 minute of bouncing and 2 minutes of shooting wheel. The re-warm-up protocols were completed 1 minute before the beginning of the second half. **Results:** The re-warm-up did not show significant effects on jump performance and rating of perceived exertion immediately after half-time and after the second half of the basketball simulated match. No significant changes were identified for heart rate and locomotory responses during the game, except for the distance covered at a very light speed which was significantly higher in the traditional group. **Conclusions:** These data support that adding a bouncing exercise to a classic re-warm-up during half-time does not lead to additional improvement in young female basketball players.
Key Words: - **intermittent exercise; performance; rest period; team sport; warm-up**

Introduction

Warm-up (WU) routines are widespread in training and sporting competitions to improve subsequent performance (Sumartiningsih et al., 2022). The main purpose of the WU is usually to generate a rise in muscle temperature (McGowan et al., 2015) which in turn is associated with an enhanced jump (Krčmár et al., 2016), improved range of motion (Bleakley & Costello, 2013) and sprint performance (De Sousa et al., 2018). Additionally, various physiological changes associated with WU have been attributed to increased muscle temperature (Bishop, 2003). For example, an improve in muscle contraction velocity (Karvonen, 1992), and muscle glycogen utilization (Starkie et al., 1999). Over the years, various WU strategies have been investigated in basketball and have generally been considered positive (Eken, 2021; Padua et al., 2019), even though the actual application of WU strategies is frequently based on individual experiences (Fradkin et al., 2010).

Due to basketball rules, the match is divided into two halves , separated by a 10-minute break (FIBA, 2020). Several studies have reported a decrease in sporting performance when the temperature drops (Galazoulas et al., 2012) and a significant increase in injuries during the first few minutes of the second half (Hawkins & Colin, 1999). In this regard, Crowley et al. (1991) found the decrement in physical performance to be in the order of ~4% per 1°C after muscle cooling. For this reason, it has been suggested that passive rest may not be beneficial to performance during this recovery period (Russell et al., 2015).Previous studies have suggested performing an active warm-up (RW-U) during the half-time (HT) period (Silva et al., 2018). Different investigations performed in intermittent team sports showed that performing RW-U methods based on cycling (R. J. Lovell et al., 2007) and strength or sport-specific exercises (Zois et al., 2013) could be beneficial for improving performance in the second half. Nevertheless, RW-U methods used in most investigations may be

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challenging to deliver to a whole team during real matches (Ramos-Campo et al., 2020; Zois et al., 2013) or longer than the available time for RW-U (Towlson et al., 2013). On the other hand, although previous literature supports using RW-U protocols to improve performance measures in team sports, most reports were on male participants in football or rugby settings (González-Devesa et al., 2021). The issue of RW-U in HT break during basketball matches is poorly studied. To the authors' knowledge, only one research addressed the usefulness of RW-U in basketball. In the study by Pociūnas et al. (2018), RW-U appeared to be effective in stimulating lower-body muscular performance. However, this investigation has some limitations that need to be considered. First, the duration of the interventions (7 minutes) does not match the time available during the basketball HT (González-Devesa et al., 2022). Second, results were only known for male athletes. Finally, they only evaluated parameters related to athletes' lower limb power. Therefore, developing a time-efficient and practically sound HT RW-U strategy for female basketball players is required. Following the above concern, this study aimed to evaluate the effects on sport performance of two different basketball-specific RW-U routines that do not demand additional equipment.

Material & methods

Participants

Ten U16 female basketball players (mean ± SD: age, 14.2 ± 1.6 years; height, 162 ± 11 cm; mass, 54 ± 14 kg) from the same team participated in the study. The intervention was conducted during the mid-season, with a typical week involving one competitive match and three training sessions. Participants were included if they had no recent history of musculoskeletal injury during the testing schedule. All of them provided informed consent before commencing any trials. The study was developed following the Declaration of Helsinki.

Experimental design This article was registered with the Open Science Framework (OSF), https://doi.org/10.17605/OSF.IO/D3BFP. The present research applied a cross-over and counterbalanced measures experimental design. Participants were required to complete two 40-minute matches, interspersed by four days, with the same subjects playing the same field position and in the same team on both occasions. The players were divided into two teams according to playing position and skill level. The two teams were selected in collaboration with the head coach and strength and conditioning coach to ensure that the teams were of equal skill levels. All experimental trials were performed at the same time of day to avoid any circadian rhythm-related variation in the results. All of them were conducted on the same indoor playing surface to remove surface interactions. The mean temperature and humidity were 16.4 ± 0.8°C and 64.5 ± 5% (mean ± SD), respectively. Participants were asked to maintain their normal lifestyle, exercise and diet throughout the study. Players reported for the trials after refraining from caffeine, alcohol, and strenuous exercise in the previous 24 h.

Procedure Figure 1 depicts a schematic representation of the main trial. Upon arrival at the basketball court, players remained seated for 15 minutes while familiarization instructions were discussed, followed by a ~15-minute standardized WU led by the team's staff. Subsequently, participants rested for 3 minutes to represent match-day practices. Then, the two teams played a simulated match of four quarters (10 minutes each), with a 10-minute break at HT and a 1-minute break after the first and the third quarters. Every simulated match was played 5 vs 5, following official basketball rules, and each team had a basketball coach. Each player played for 40 minutes, as substitutions were not allowed, staying in the match even when they had five fouls.

During the 10-minute HT break, players executed two types of RW-U in a randomized order. A tactical simulation was performed for 6 minutes, followed by 3 minutes of basketball-specific shooting (G1). Conversely, athletes listened to tactical instructions from coaches for 6 minutes, followed by 1 minute of single-leg bouncing (8x2 bounds to each leg) and 2 minutes of shooting at the basket (G2). The RW-U protocols were completed 1 minute before the beginning of the second half.

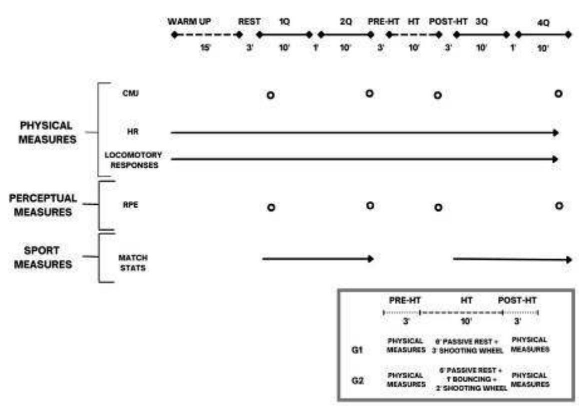

Fig. 1. Schematic representation of the experimental design. Circles depict point measurements, and horizontal arrows depict values recorded continuously. Abbreviations: CMJ = counter-movement jump; G = group; HR = heart rate; HT = half-time; Q = quarter; RPE = rating of perceived exertion; WU = warm-up.

Measurements

Lower-body muscular strength: The participants were required to complete two maximal trials of the CMJ. The best result was used for data analysis. The jumps were performed on a jump mat (Bosco-System, Barcelona, Spain). Subjects were instructed to flex their knees (approximately 90) as quickly as possible and then jump as high as possible in the ensuing concentric phase to standardize CMJ trials. Arms were in a steady position with hands on hips. The landing was performed simultaneously with both feet while maintaining ankle dorsiflexion and with the legs straight during the flight phase of the jump. Jump trials not meeting these conditions were deemed invalid, and participants repeated the trial. Perceptual measures: Participants' rating of perceived exertion (RPE) was assessed using Borg's 6-20 point scale (Borg, 1982).

Cardiovascular and locomotory responses: The Polar Team Pro System (Polar Electro OY, Kempele, Finland) integrates multiple sensors (e.g. 10 Hz GPS, accelerometer, gyroscope, digital compass, sampling at 200 Hz) coupled with in-built HR monitoring. It was used to determine velocity and distance indoors and record HR continuously at 1-s intervals during the trials.

Match stats: During the matches, all players were filmed in close-up with a digital video camera (Panasonic Hc-V180; Panasonic Corporation of North America, One Panasonic Way, Secaucus, NJ). The camera was positioned (height of ~3 m and distance of 4-5 m from the touchline) at the corner of the pitch. The same experienced evaluator analyzed all recordings. Data on-court performance variables were collected separately for each trial and were also combined into one database of all the trials following the FIBA statisticians' manual (FIBA, 2018). The variables were as follows: points (PTS), team free-throw shot percentage (FT%), team 2-point shot percentage (2P%), team 3-point shots percentage (3P%), defensive rebounds (DREB), offensive rebounds (OREB), assists (AST), turnovers (TO), steals (STL), blocks made by the team (BLK), blocks received (BLK-ON), fouls committed by the team (PF), and fouls received (PF-ON), performance index rating (PIR). The obtained equation to calculate the PIR scores for each player's performance was as follows (Ibáñez et al., 2018):
PIR = (PTS+ TREB + AST + STL + BLK committed + PF-ON) – (1P missed+ 2p missed+ 3p missed+ TO + PF committed+ STL received) Nonetheless, intra-observer reliability was tested by asking the observer to analyze the matches twice 15 days apart, and the results showed an intraclass correlation coefficient of 0.97-0.99, excellent reliability (Koo & Li, 2016).

The players completed four-point measurements for CMJ and RPE: (a) after the pre-match WU; before the start of the first quarter; (b) after the first half, before the start of the HT period; (c) after the HT period, just before the start of the second half; and d) just after the match ended. The tests were performed in the same order during all test occasions, undertaking a 3-minute testing period for each performance assessment. Polar sensors and video recordings were activated from 20 minutes before the start of the match until 5 minutes after the end of the match, with continuous recordings (illustrated in Fig. 1).

Statistical analysis

Statistics were computed using Statistical Package for the Social Sciences (SPSS v24, Armonk, NY: IBM Corp.) All values are shown as mean ± SD unless otherwise stated. Statistical significance was set at $p < 0.05$. The Shapiro–Wilk test was performed to check for normality of distribution. Two-way repeated measures analysis of variance (ANOVA; trial x time) was used where data contained multiple time points. The assumption of homogeneity of variance was verified with Levene's Test. Mauchly's test was consulted, and Greenhouse–Geisser correction was applied if sphericity was violated. Significant main effects of time were further investigated using pairwise comparisons with Bonferroni confidence-interval adjustment. The correlation coefficients were determined by using Pearson's product-moment test. Effect sizes (ESs; $\eta 2$) were calculated, and values of 0.01, 0.06, and >0.15 were considered small, medium, and large, respectively (Cohen, 1988). The differences in HR between the matches and the first and second halves were tested with Student's paired t-test.

A descriptive analysis of the match statistics was carried out to help contextualize the match. The differences between groups were expressed in percentage units with 95% confidence limits. Between sessions, reliability was assessed using intraclass correlation coefficients (ICC) from the pre-HT measures. The ICC values were then used to determine the minimal detectable difference (MDD) via the calculation of the standard error of measurement (SEM). The calculation was performed using these formulas: $SEM = [SD \cdot \sqrt{(1-ICC)}]$ and $MDC = [1.96 \cdot SEM \cdot \sqrt{2(1-ICC)}]$, where SD represents the standard deviation of the differences between the sessions, and 1.96 is the z-score corresponding to 95% CI, respectively (Atkinson & Nevill, 1998).

Results

All players completed all games. One participant had missing data on HR and locomotory responses during the second match due to an error with the devices. Data were presented for 9 participants on these variables.

Lower-body muscular strength

There were no main effects of trial and trial × time interaction for CMJ (Fig. 2). The post-hoc test revealed that before starting the matches, there were no differences in the players' CMJ performance between G1 and G2

(23.4 ± 3.5 vs 24.4 ± 3.7 cm). Also, no significant differences were found between interventions in jumping performance during trials. However, after the HT period, CMJ performance increased by 2.9% during G1 (24.5 ± 3.6 cm) and reduced by 2.4% during G2 (24 ± 3.7 cm).

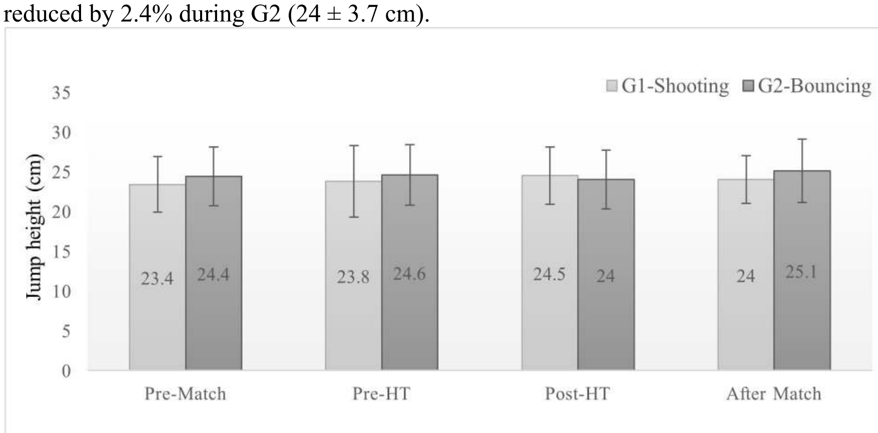

Fig. 2. Mean ± SD peak height of the counter-movement jump during both trials. Abbreviations: G = group; HT = half-time.

Heart Rate and Rating of Perceived Exertion

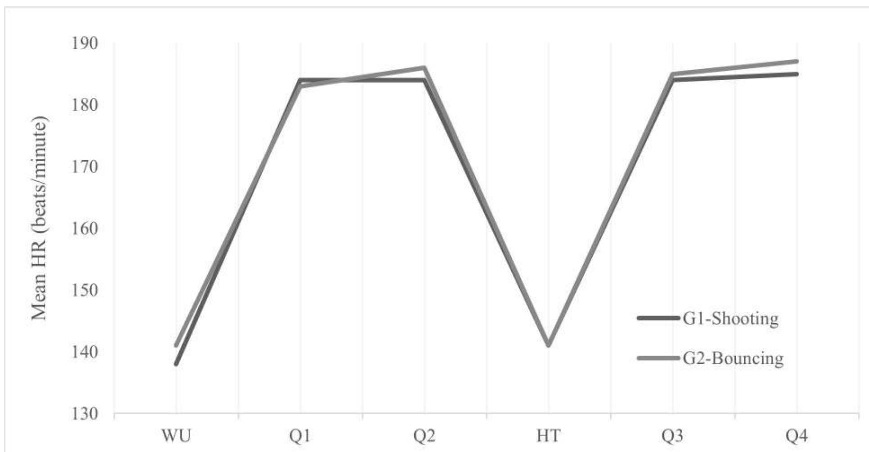

Fig. 3. The mean heart rate between the two trials. Abbreviations: G = group; HR = heart rate; HT = half-time; Q = quarter; WU = warm-up.

There was a main effect for time interaction ($p < 0.05$) for the mean HR. The mean HR for the players during the two matches was 167 ± 6 and 169 ± 4 beats/minute for G1 and G2, respectively, which corresponded to 84% ± 3% (G1) and 84% ± 2% (G2) of peak HR. There were no significant differences among both trials for the mean HR during the matches (Fig. 3).

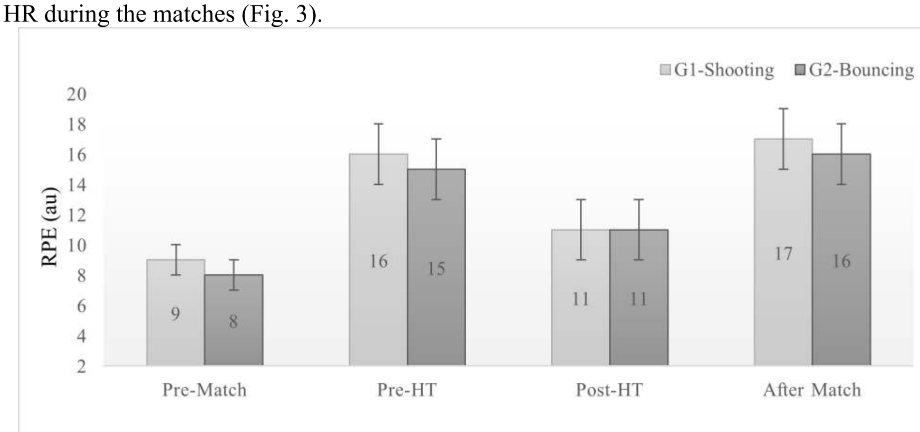

Fig. 4. Mean ± SD of rating of perceived exertion during both trials. Abbreviations: G = group; HT = half-time; RPE = rating of perceived exertion.

There was a main effect for time interaction ($p < 0.05$) for the RPE, with increasing values after playing time and decreasing after HT (Fig. 4). There were no differences in perceived fatigue between the interventions.

Locomotory Responses

The total session distance and match velocity were ~5338 m and 3.84 km·h^{-1}, respectively. No significant differences in total and mean session distance were evident between the group and stages. According to the intervention, no significant differences were found for all velocity categories except very light. In this sense, G1 covered a significantly greater distance (G1: 2287 ± 153 vs G2: 1976 ± 180 m) within this speed category (large ES) during the sessions compared to G2 (Table 1).

Table 1. Mean (SD) locomotory responses during both matches.

	G1 (n=9)	G2 (n=10)	P value	ES (d)
Total session distance (m)	5602 (514)	5100 (597)	0.07	0.183
Mean session velocity (km·h^{-1})	3.81 (0.35)	3.85 (0.43)	0.85	0.002
Distance covered during session within velocity category (m)				
Very light	2287 (153)	1976 (180)	0.01	0.487
Light	1227 (186)	1151 (248)	0.46	0.032
Moderate	1061 (251)	997 (192)	0.54	0.023
Hard	546 (300)	536 (304)	0.94	0.000
Very hard	200 (199)	195 (181)	0.95	0.000

Abbreviations: m = metre; m·min^{-1} = metres per minute; km·h^{-1} = kilometres per hour; ES = effect size. Note: Very light, 3–6.99 km·h^{-1}; Light, 7–10.99 km·h^{-1}; Moderate, 11–14.99 km·h^{-1}; Hard, 15–18.99 km·h^{-1}; Very hard, >19 km·h^{-1}.

In terms of intensity ranges, a higher percentage of accelerations and decelerations was found between -1.99 to 1.99 m/s². There were no statistically significant differences in the intensity of accelerations and decelerations between interventions during all matches and immediately post-HT (Fig. 5).

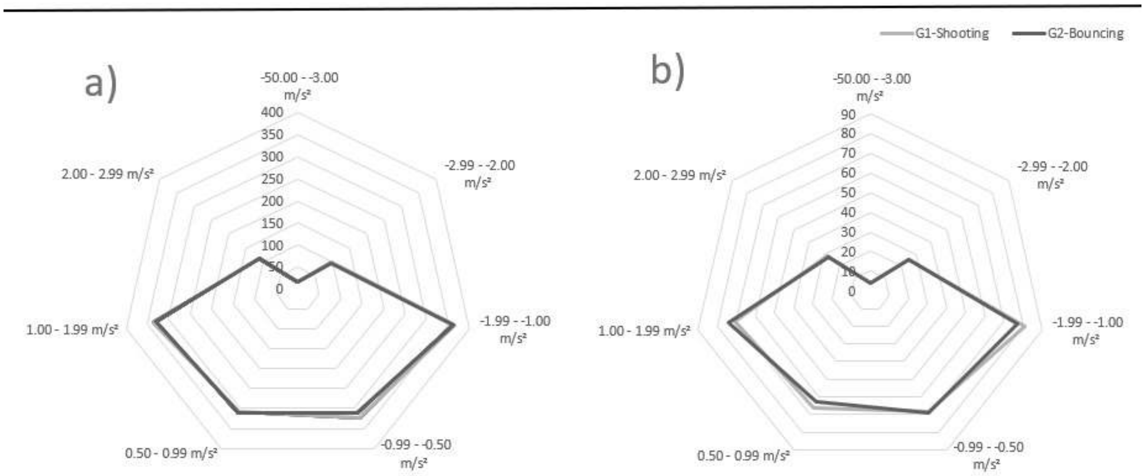

Fig. 5. a) Number of accelerations per match; b) Number of accelerations in the third quarter. Abbreviations: G = group.

Match Stats

Table 2 presents descriptive statistics for the individual stats. In the two matches of this study, a total of 668 actions were analyzed. In general, the bouncing group excelled over their shooting group counterparts in PTS, OREB, DREB, TREB, TO, 2P made, 1P%, 3P%.

During Q3, the bouncing group showed better results in PTS, OREB, DREB, TREB, PF, FT made, 2P made, 1P%, 2P%. In terms of PIR, it was detected a better overall match performance of the bouncing group during both matches and Q3.

Table 2. Mean (SD) match stats during trials by player.

	Total		In Q3	
	G1 n=10	G2 n=10	G1 n=10	G2 n=10
Total Match Win	*0*	*2*	-	-
Total Match Lost	*2*	*0*	-	-
Total Score	*70*	*82*	*12*	*26*
PIR	6.3 (11.5)	8.4 (8)	-0.1 (4.8)	3.7 (2.8)
PTS	6.8 (5.8)	8.2 (4.3)	1.2 (2.2)	2.6 (2.5)
OREB	2.3 (3.7)	2.6 (2.1)	0.3 (0.7)	0.8 (1)
DREB	3.8 (2)	3.9 (2.5)	0.9 (0.6)	1.5 (0.9)
TREB	6.1 (5.2)	6.5 (3)	1.2 (1)	2.3 (1.1)
BLK	1 (2.8)	0.5 (1.3)	0.3 (0.9)	0.3 (0.7)
STL	4.4 (1.8)	4.2 (2)	1 (1.1)	0.9 (1)
TO	5 (3.6)	4.6 (1.2)	1 (0.7)	1.1 (1)
AST	2.1 (1.1)	2 (1.2)	0.4 (0.7)	0.4 (0.5)
PF	1.1 (1.1)	1.2 (1.4)	0.7 (0.8)	0.2 (0.4)
3P made	1.9 (1.5)	1.7 (1.4)	0.5 (0.7)	0.4 (0.7)
2P made	8 (4.7)	8.8 (4.2)	2.1 (1.7)	2.4 (2)
FT made	1.7 (1.8)	1.5 (2.6)	0.4 (0.8)	0.6 (1)
3P%	11.7 (19.3)	15 (31.6)	0	0
2P%	37.2 (27.1)	34.6 (18)	21 (36)	38.2 (33.1)
FT%	5 (15.8)	18.75 (34)	0	20 (42.2)

Abbreviations: AST = assists; BLK = blocks made; DREB = defensive rebounds; PIR = performance index rating; FT = free-throw shot; OREB = offensive rebounds; PF = fouls committed; PTS = points; Q3 = third quarter; STL = steals; TO = turnover; TREB = Total rebounds; 2P = 2-point shots; 3P = 3-point shots.

Discussion

The present study aimed to compare the efficacy of traditional vs alternative RW-U strategies implemented during the HT of a simulated basketball match on physical, perceptual and sport-specific measures. This work could help basketball coaches and players to deliver their strategies during HT.

The main findings of the current study were that both interventions had similar effects in terms of lower-body muscular strength, HR, RPE and locomotory responses. In contrast, the bouncing-based intervention had better results regarding match stats.

Performing no RW-U was associated with decrements in maximal high jump immediately after HT (Edholm et al., 2015). In the current study, the bouncing-based intervention reduced its performance slightly after the intervention, while the traditional intervention increased jump height by 2.9%. Only one other investigation (Pociūnas et al., 2018) assessed jump performance through CMJ after HT in simulated match basketball. However, the differences between the populations (age, gender and competitive level) make comparison difficult.

Concerning the data obtained, the mean HR for both groups was ~84%, which agrees with that reported during basketball matches in other research (Stojanović et al., 2018). Nevertheless, there were no significant differences in HR and RPE after the RW-U strategies. The latter may occur because both strategies have a similar duration and intensity.

It has previously been suggested that when compared to calisthenic exercises, heavy resistance exercises may result in a match advantage in soccer (Edholm et al., 2015). However, the RW-U strategies used in previous studies (Edholm et al., 2015; Mohr et al., 2004; Russell et al., 2018) may be difficult to apply due to their duration, which is longer than 3 minutes (Towlson et al., 2013). To our knowledge, the present study is the first to observe the influence of short-duration RW-U strategies that do not require additional equipment during simulated basketball matches. The latter fact could facilitate its implementation.

On the other hand, during these simulated matches, locomotor data were not significantly different between conditions. The latter suggests that movement efficiency is not altered after the HT period, except for the total distance travelled at a very light speed, which was higher in the traditional intervention group. These data align with previous studies of actual U18 matches (Hůlka et al., 2013). Although the implemented design tries to limit confounding variables, match-to-match variation in locomotory responses, especially high-intensity running and sprinting, has been demonstrated to be high and impairs the use of real matches when evaluating interventions for these variables (Gregson et al., 2010).

Notably, this is the first study we acknowledge to have studied RW-U strategies in female players. Moreover, a novel observation of this research was the descriptive analysis of match statistics, which helped to provide additional information on the interventions and contextualized the results. Although the players had a similar workload during a simulated match in comparison with other actual matches (Hůlka et al., 2013; Stojanović et al., 2018), it cannot be stated that the intervention performed has a causal relationship with the match statistics, with the bouncing-based intervention performing better for these variables.

Despite the insights provided by this study, some limitations need to be considered. First, the sample of participants impedes a comparison with professional athletes, as the latter possess increased fatigue resistance and the ability to elicit a PAP effect in performance better (Tillin & Bishop, 2009). Nonetheless, it would be interesting to determine whether the RW-U used in this work would have similar effects at a professional level. Another limitation is relying on a simulated match environment to assess performance changes attributable to the RW-U strategies. Future investigations should analyze them during actual matches. Moreover, alternative RW-U methods may contemplate the inclusion of isometrics or maximal strength exercises. For instance, flight height has been previously employed as a variable to assess lower-body muscular strength (Fashioni et al., 2020; Lovell et al., 2013); however, it may be more appropriate to use peak power output to evaluate fatigue in CMJ (Knihs et al., 2021). Future research should take this aspect into account. For these reasons, further studies are warranted to establish the RW-U responses during the second half of the basketball matches, especially given the wide variety of RW-U protocols adopted by researchers (Silva et al., 2018).

Conclusions

The traditional RW-U based on a shooting wheel showed no significant differences compared to an alternative RW-U based on bouncing plus shooting wheel implemented before the second half of a simulated match in jump height, HR, RPE and locomotory responses. This research suggests that adding a bouncing exercise to a classic RW-U does not lead to additional improvement in young female basketball players. However, this study also shows that jumping capacity does not show significant decreases if a short-duration, high-intensity RW-U regime is performed during HT. As such, both interventions could be appropriate to implement during HT.

These findings offer practitioners and players alternative strategies that can be implemented depending on preference in basketball matches, and these results add to the strong rationale that an active RW-U has no adverse effects during the second half of simulated basketball games.

Conflicts of interest - The authors report there are no competing interests to declare.

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