Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 5), Art 126, pp. 1099 - 1108, May 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Evaluating the impact of a 3-min moderate-intensity re-warm-up protocol on basketball player performance

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Published online: May 31, 2024
Accepted for publication : May 15, 2024
DOI:10.7752/jpes.2024.05126

Abstract
Problem Statement: Despite the importance of warm-up routines in optimizing athletic performance, periods of passive rest during basketball games often lead to decreased physical capabilities among players. ***Purpose:*** The aim of this study was to determine whether a 3-min cycling Re-Warm Up (RWU) protocol of moderate intensity (40% of VO_2max) could mitigate the adverse effects of passive rest on the physical abilities of substitute basketball players. ***Methods:*** Following a structured basketball warm-up (WU), 13 semi-professional basketball players completed two trials on consecutive days in random order: (a) 15-min of passive rest (CON) or b) 11-min of passive rest, followed by 3-min of cycling at 40% VO_2max and 1-min of rest (RWU40). ***Results:*** Heart rate (HR), body temperature (BT), countermovement jump (CMJ), modified agility t-test (MAT) and rating of perceived exertion (RPE) were measured post-WU and post-RWU. Participants exhibited significant reductions in HR (-24.51%, $p < .001$), BT (-1.48%, $p < .001$), CMJ (-5.1%, $p < .001$) and MAT (-3.13%, $p = .030$) following 15 minutes of passive rest (CON) compared to post-WU measurement. In contrast, the implementation of the RWU40 protocol effectively attenuated these reductions in HR (-9.12%, $p = .017$), BT (-0.33%, $p = .375$), CMJ (-1.72%, $p = .167$) and MAT (-0.48%, $p = .634$). Additionally, participants reported higher RPE levels in the RWU40 than in the CON post-RWU ($p = .035$). ***Conclusions:*** The findings highlight the efficacy of a 3-min moderate-intensity cycle ergometer RWU in attenuating the detrimental effects of passive rest on basketball players' performance, thereby optimizing readiness for substitutes entering the game.
Keywords: Basketball, Re-Warm up, Body Temperature, Countermovement Jump, Modified Agility t-Test.

Introduction

Warm-up (WU) usually precedes athletic activities and is considered essential for optimizing performance (McGowan et al., 2015). It reduces joint stiffness, increases nerve impulse transmission and modifies the force-velocity relationship (Bishop, 2003). Furthermore, a well-structured WU elevates heart rate, enhances blood flow, accelerates muscle function and improves reaction time and psychological readiness (Woods et al., 2007), which results in enhanced physical performance (Fradkin et al., 2010).

Active WU involves movements that activate the major muscle groups and enhance short (≤10 s), medium (>10 s) and long-term (≥5 min) performance by primarily increasing muscle and body temperature (Bishop, 2003) which in general enhances neuromuscular function (Lovell et al., 2007). In contrast, prolonged rest periods lower body temperature, impair muscle function and decrease performance (Bishop et al., 2008). During football halftime (HT), passive rest has previously led to core and muscle temperature drops (Lovell et al., 2007; Mohr et al., 2004) accompanied by a decline in sprint (Mohr et al., 2004) and endurance performance (Lovell et al., 2007), while in other studies, VO_2 levels returned to near-resting levels within 5 min (Özyener et al., 2001). Every 1°C decrease in muscle temperature results in an approximately 3% reduction in muscle power (Sargeant, 1987). Basketball players presented a 13% decline in countermovement jump (CMJ) and a 4% decrease in 20m sprint performance after a 10-min bench rest (Galazoulas et al., 2012). Notably, this performance decrease became even larger after a 40-min rest, reaching 20% for CMJ and 6% for the 20m sprint (Galazoulas et al., 2012).

Re-warm-up (RWU) strategies have been adopted to overcome the negative effects of passive rest on performance in basketball players, either during half time or during the game (Koutsouridis et al., 2023, Silva et al., 2018). RWU seems to attenuate temperature and performance decrements during HT in soccer players (Hammami et al., 2016). A range of 1-7-min RWU protocols' durations has been previously proven effective in team sport athletes to prevent any detrimental effects on performance (Mohr et al., 2004; Yanaoka et al., 2018a;

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Yanaoka et al., 2018b; Fashioni et al., 2020; Yanaoka et al., 2021) with the short-lasting ones being more applicable in game situations than the long-lasting ones.

The effectiveness of WU and RWU is associated with the net balance between potentiation and fatigue (Bishop, 2003; Boullosa et al., 2018). Higher intensity protocols cause greater elevation of temperature and muscle activation compared to low-intensity protocols but also cause greater fatigue (Bishop, 2003), which may impair performance or mask the potentiation effect for a certain time frame (Blazevich & Babault, 2019). Furthermore, long-duration, low-intensity WU protocols were proven to be as effective as short-duration high-intensity WU protocols on a cycle-ergometer when their volumes were matched (Yanaoka et al., 2020). Therefore, it may be assumed that WU and/or RWU protocols of various intensities may be effective for performance indices and further investigation is needed to find the most suitable RWU protocol according to the different physiological profiles of each sport.

Research on RWU in basketball is limited during HT (Pociūnas et al., 2018; González-Devesa et al., 2023). Passive rest during basketball games may reduce performance and increase the risk of injury owing to muscle temperature loss (González-Devesa et al., 2023). Substitutes may remain seated for extended periods, even exceeding 15 min (Alberti et al., 2014). According to the official basketball rules, during playing time, all substitutes should remain seated and only the coach or the first assistant coach - but only one of them at a time - is allowed to remain standing during the game (FIBA, 2023). Thus, the use of RWU protocols involving jumps, changes in direction, dribbling, or anything else that require substitute players to stand is prohibited under the regulations to be applied during the game. This makes all the previously suggested RWU protocols applicable only to HT. To our knowledge, only one study has examined the effect of different RWU-seated activities on performance during a basketball game (Alberti et al., 2014), reporting that all players, regardless of seated RWU activity, experienced an approximately 8.5% jump height decline following 20 min of resting on the bench.

Given the lack of research investigating RWU protocols during a basketball game and FIBA's restrictions prohibiting any standing RWU activity during the game (FIBA, 2023), there is a need (a) to develop a RWU protocol that is practically applicable to basketball game conditions and (b) to assess its effect on crucial basketball performance indices such as countermovement jump and change of direction. Thus, the aim of the present study was to assess performance, temperature, heart rate and perceptual responses after the completion of a 3-min cycling RWU protocol of moderate intensity (40% of VO_2max), which is permitted to be applied during a basketball game, when compared to a passive condition. We hypothesized that the RWU protocol would have a positive effect on all variables measured in comparison to passive rest.

Materials and Methods

Participants

The sample size for this study was determined using G*power 3.1 software, taking into account data from a previous study (Yanaoka et al., 2020) that examined the impact of high-intensity cycling RWU performed within a very short time frame on intermittent sprint performance. Based on an effect size (ES) of 1.0, an α-level of 0.05, and a power of 0.8, (Yanaoka et al., 2021) the analysis indicated that a minimum of 10 participants was necessary. The sample of the research consisted of 13 semi-professional basketball players with average age 20.54±1.45 years, training age 9.08±3.2 years who perform 3.92±1.32 training sessions per week. Participants' characteristics are presented in Table 1. All participants signed a consent form after receiving clarifications regarding the aims, procedures, and potential hazards of the study. All procedures were performed in accordance with the code of the local ethics committee and the Declaration of Helsinki.

Table 1: Characteristics of the participants (mean ± SD).

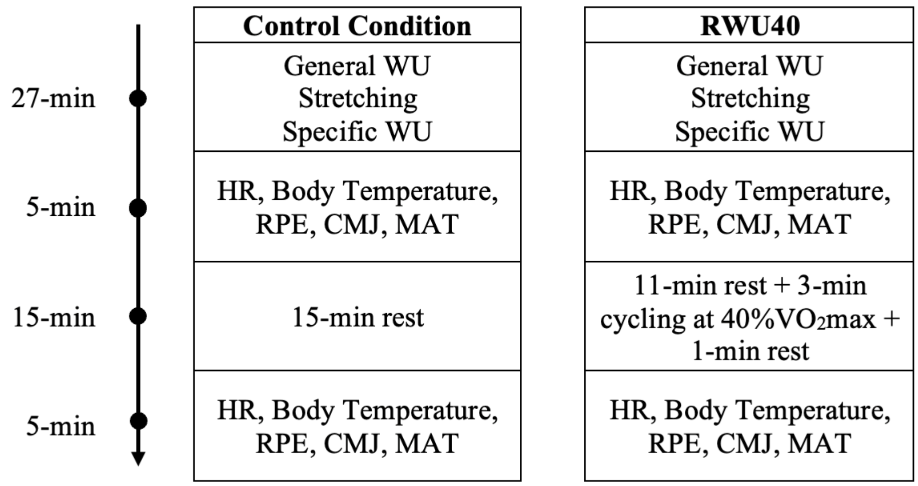
	Min	Max	Mean ± SD
Age (years)	19	23	20.54 ± 1.450
Training Age (years)	3	13	9.08 ± 3.201
Trainings per week	2	6	3.92 ± 1.320
Body mass (kg)	70.8	90.5	81.36 ± 6.354
Height (m)	1.726	1.95	1.82 ± 6.975
BMI (kg/m^2)	21.8	28.77	24.34 ± 2.093
Body Fat (%)	5.51	22.43	12.34 ± 4.602
VO_2max (ml/min/kg)	36.48	60.29	50.26 ± 5.711
Watts at VO_2max	224	320	292.31 ± 25.637
7.5% of BM (kg)	5.31	6.79	6.10 ± 0.476
Resting HR (bpm)	46	94	75.71 ± 11.137
HRmax (bpm)	178	199	188.23 ± 5.718
VEmax (l/min):	118.3	194.9	165.41 ± 27.548
RER:	1.01	1.14	1.08 ± 0.039
Resting Body Temp. (^{o}C):	35.4	37	36.16 ± 0.436

BM: Body Mass, BMI = Body Mass Index, bpm= beats per minute, HR = Heart Rate, RER = Respiratory Exchange Ratio, VEmax = Ventilation at Maximal Exercise, VO_2max = Maximum Oxygen Uptake.

Experimental design

Using a counterbalanced, randomized order, and repeated measures design, all participants completed two experimental sessions after a preliminary visit when their maximum oxygen uptake (VO_2max) was determined. On two consecutive days, the athletes performed a WU similar to that typically performed prior to a basketball game, after which their HR, body temperature, Rating of Perceived Exertion (RPE), CMJ and Modified Agility T-test (MAT)

performance were measured. Following the WU and initial measurements (post-WU), the athletes performed



either 15 min of passive rest (CON) or 11 min of passive rest followed by a 3-min RWU protocol at 40% VO_2max (RWU40). The target for reintegration of the athletes in the recurring measurements (post-RWU) was

Figure 1: Characteristics of the participants (mean ± SD).

15 min. The study design is illustrated in Figure 1.

The selection of this time frame was based on the athletes' rest times. The first substitutions occur after 3-6 minutes of play, which in real time was 6-12 minutes following the start of the game (Alberti et al., 2014). Because not every bench player enters the game during the initial substitution period, the time spent in the seated position for the rest players can exceed, even 15 min (Alberti et al., 2014).

Participants were asked not to change their lifestyle habits, exercise, or diet throughout the study. Participants recorded all meals and drinks consumed the day before each trial and replicated their dietary intake in subsequent trials, ensuring that meals were standardized across trials. They abstained from alcohol and caffeine intake 24 h before each experimental trial. During rest, the players remained seated on the bench and had access to water *ad libitum.*

Procedure

One week prior to the measurements, the participants were provided detailed instructions for the implementation of the study. Over the course of this week, preliminary measurements were performed (mass, height and body fat percentage). The height and mass of the athletes was recorded and measured with an accuracy of 0.1 cm and 0.1 kg, by an electronic scale with a stadiometer (Seca 220e, Hamburg, Germany). The skinfold measurement was conducted by the same experienced assessor using seven skinfold sites (tricep, subscapular, chest, midaxillary, suprailiac, abdominal and thigh) and the Jackson & Pollock (1978) equation. A graded exercise test on a Monark Ergomedic 874E cycle ergometer was used to determine the individual VO_2max and the corresponding power in watts. The participants also performed multiple trials during the preliminary week to familiarize themselves with the testing procedures.

Subsequently, two consecutive days were allocated for the purpose of measurements, with each measurement session being conducted 24 h apart from the previous one. To minimize the potential influence of circadian variations, all measurements for each athlete were taken at the same time of the day, with a maximum difference of 15 min. The average ambient temperature and humidity during the measurements were 17.4 ± 1.2°C and 46.7 ± 6.5% respectively.

The athletes were randomly divided into two groups. On the first day of the experiment, half of the athletes underwent the measurement procedure of the CON condition and remained seated on the bench for 15 min, whereas the rest performed RWU40 on the cycle ergometer. On the following day, the groups underwent the opposite procedure.

Initially, the athletes performed a typical basketball WU with a duration of 27 min, as they do before the commencement of a game (Galazoulas et al., 2012). The WU consisted of 7.5 min of general WU, 8.5 min of dynamic stretching, and 11 min of specific WU adapted to basketball. The general part of the WU focuses on increasing core and muscle temperatures and range of motion (Zentz et al., 1998). The specific part is related to the activity that follows and focuses on the reinforcement of motor patterns (Bishop, 2003).

Following WU, the athletes underwent post-WU measurements to assess their optimum sports performance. These measurements included body temperature, HR, RPE questionnaire, three CMJs and one MAT. Subsequently, the athletes completed one of two protocols. Each protocol was terminated one minute before the onset of the evaluation trials. Following the conclusion of each protocol, measurements were repeated for each group (post-RWU).

Measurements

VO_2max assessment: VO_2max was measured using a graded exercise test with a cycle ergometer. The participants were instructed to maintain a consistent cadence of 80 revolutions per minute (rpm) during cycling. The exercise protocol commenced with a workload of 1.2 kg, corresponding to 96 W, which was sustained for a duration of 3-min. Subsequently, the workload was increased to 1.9 kg, equivalent to 152 W, and sustained for an additional three minutes. Thereafter, the load was augmented by 0.3 kg every minute until voluntary exhaustion was achieved. Using an automatic gas analyzer (AE-310s, Minato Medical Science, Japan), oxygen uptake (VO_2) was measured breath-by-breath and averaged over 15s intervals. When two of the following three criteria were satisfied, VO_2max was calculated: 1) VO_2 levelling off, 2) HR exceeding 90% of the maximum rate (220 - age) and 3) respiratory exchange ratio exceeding 1.05.

Physiological measures: Body temperature was assessed using an infrared ear thermometer (TotiFar CT-30DX, OST, Jsinchu, Taiwan) (Galazoulas et al., 2012). Measurements were obtained prior to WU, immediately after, and at the end of each protocol. The HR data were collected using the Polar Team Pro system (Kempele, Finland). First, resting HR was recorded as a baseline measurement, conducted prior to the initiation of any physical activity, following a minimum 5-min period of rest on the bench. Subsequently, HR measurements were acquired immediately after WU and after the RWU protocol.

Performance: The CMJ was selected in the present study for the assessment of the participants' vertical jump and vicariously the explosive power of the legs. The athletes rested their arms on their hips, bent their knees and jumped as high as possible without pausing. The amplitude of knee flexion during the CMJ was self-selected and the participants were asked to try and land on both feet close to the take-off point. Three consecutive jumps were performed at an interval of 30 s and were recorded using the OptojumpTM system (Microgate, Bolzano, Italy). The highest jump was considered and used for the statistical analysis. Pearson correlation analysis showed a strong agreement among the three CMJ measurements (r > 0.934), indicating high measurement reliability.

MAT was chosen to evaluate the athletes' agility performance. All trials were timed with 0.001s precision using a Witty photocell system (Microgate, Bolzano, Italy). Photocells were mounted on tripods and placed at hip height to avoid recording incorrect signals from the limbs (hands). The two tripods were positioned 3 m apart facing each other, with a starting line between them. The participants started from a starting point with the leading foot placed 50 cm behind the starting line to eliminate the reaction time factor. Specifically, players

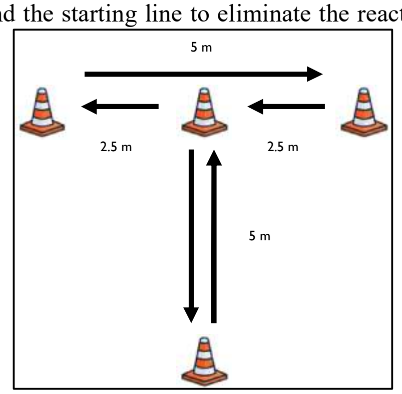


Figure 2: Modified Agility T-test

completed a forward linear sprint for 5 m, lateral-leftward shuffle for 2.5 m, lateral-rightward shuffle for 5 m, lateral-leftward shuffle for 2.5 m, and linear backpedal for 5 m. A cone (height 30 cm) was placed at each point of change in direction, where the players had to touch the top (Figure 2). Participants performed the test once.

The RPE was assessed using the 10-point Borg (1982) scale prior to the post-WU and post-RWU measurements.

Statistical Analysis

Statistical analysis was conducted using SPSS software (version 28.0, SPSS Japan Inc., Tokyo, Japan). All values are shown as the mean ± SD. To ensure model suitability, the assumptions of the general linear model (GLM) were assessed. A two-way repeated-measures test (2 × 2, Time × Protocol) was used to compare differences between measurement times and protocols. The Bonferroni method was used for post-hoc multiple comparisons if significant interactions and trial effects were observed. The level of statistical significance was set at $p < 0.05$. Partial eta squared values were also calculated to determine the effect size for all main effects and interactions, with the effects classified as small (0.01 – 0.059), moderate (0.06 – 0.137), and large (> 0.138) (Richardson, 2011). Additionally, Cohen's d effect sizes with a 95% confidence interval were reported, where values greater than 2.0 were considered a very large effect, 1.2 – 2.0 as a large effect, 0.6 – 1.2 as a moderate effect, 0.2 – 0.6 as a small effect, and 0.19 or lower as a trivial effect (Hopkins et al., 2009).

Results

The means, standard deviations, percentage differences (PD), p-values and Cohen's d effect sizes for all measurements are shown in Table 2.

Table 2: Statistical results. Means for post-WU and post-RWU measurements ± SD, percentage differences (PD), p-values and Cohen's d effect sizes.

Variable	Group	PostWU	PostRWU	Mean Diff.	PD	Sig.	Cohen's d
HR (bpm)	CON	130.23 ± 16.39	98.31 ± 12.05	31.92 ± 13.81	-24.51%	<.001*	2.310
	RWU40	132.38 ± 17.65	120.31 ± 19.50	12.07 ±15.69	-9.12%	.017*	0.769
Body Temp. (°C)	CON	37.01 ± .67	36.46 ± .39	0.54 ± .39	-1.48%	<.001*	1.398
	RWU40	36.93 ± .69	36.81 ± .63	0.12 ± .48	-0.33%	.375	0.256
CMJ (cm)	CON	36.81 ± 2.13	34.93 ± 1.97	1.87 ± 1.08	-5.10%	<.001*	1.723
	RWU40	37.10 ± 2.42	36.46 ± 2.22	0.63 ± 1.56	-1.72%	.167	0.408
MAT (s)	CON	6.24 ± .40	6.44 ± .29	-0.19 ± .28	3.13%	.030*	0.680
	RWU40	6.20 ± .47	6.23 ± .29	-0.03 ± .22	0.48%	.634	0.136
Perceived Exertion	CON	2.23 ± .94	1.19 ± .77	1.03 ± 1.00	-46.57%	.003*	1.029
	RWU40	2.19 ± 1.03	2.19 ± 1.09	0 ± 1.27	0.00%	1.000	0.000

The results of the two-way repeated measures ANOVA revealed a significant main effect of Time ($F = 37.258$, $p < .001$, $\eta_p^2 = .756$), indicating a significant difference in HR between post-WU and post-RWU measurements in both groups (CON: $p < .001$, $d = 2.310$, PD = -24.51%; RWU40: $p = .017$, $d = .769$, PD = -9.12%). The Time x Protocol interaction effect was also significant ($F = 25.712$, $p < .001$, $\eta_p^2 = .682$), as HR was higher in RWU40 than in CON post-RWU ($p < .001$, $d = 1.685$).

With regard to body temperature, there was a significant main effect of Time ($F = 19.260$, $p < .001$, $\eta_p^2 = .616$). Significant differences were observed in body temperature between post-WU and post-RWU in CON, but not in RWU40 (CON: $p < .001$, $d = 1.398$, PD = -1.48%; RWU40: $p = .375$, $d = .256$, PD = -.33%). The Time × Protocol interaction effect was also significant ($F = 4.984$, $p = .045$, $\eta_p^2 = .293$). Body temperature was greater in the RWU40 compared than in the CON post-RWU, although the difference was not statistically significant ($p = .051$, $d = 0.600$).

Time had a significant main effect on CMJ ($F = 40.194$, $p < .001$, $\eta_p^2 = .770$). The difference between the post-WU and post-RWU measurements was significant in the CON but not in the RWU40 (CON: $p < .001$, $d = 1.723$, PD = -5.1%; RWU40: $p = .167$, $d = .408$, PD = -1.72%). The Time × Protocol interaction effect was not significant ($F = 3.808$, $p = .075$, $\eta_p^2 = .241$); however, CMJ was higher in the RWU40 than in the CON post-RWU ($p = .031$, $d = 0.679$).

There was a non-significant main effect of either Time ($F = 3.849$, $p = .073$, $\eta_p^2 = .243$) or the Time × Protocol interaction ($F = 3.892$, $p = .072$, $\eta_p^2 = .245$) for MAT. The difference between the post-WU and post-RWU measurements was significant in CON but not in RWU40 (CON: $p = .030$, $d = 0.680$, PD = 3.13%; RWU40: $p = .634$, $d = 0.136$, PD = .48%). Moreover, MAT performance was higher in the RWU40 than in the CON post-RWU ($p < .001$, $d = 0.679$).

There was a non-significant main effect of Time for RPE ($F = 4.13$, $p = .065$, $\eta_p^2 = .256$) but a significant effect of Time × Protocol interaction ($F = 7.401$, $p = .019$, $\eta_p^2 = .381$). The difference between post-WU and post-RWU measurements was significant in CON but not in RWU40 (CON: $p = .003$, $d =1.029$, PD = -

46.57%; RWU40: p = 1.000, d=0.00, PD = 0%). In addition, RPE was higher in the RWU40 than in the CON post-RWU (p = .035, d = 0.661).

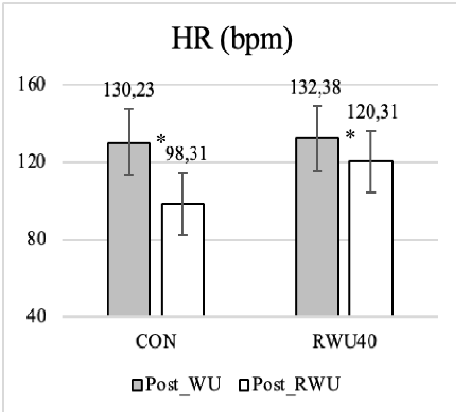


Figure 3: Means of HR for post-WU and post-RWU for the two protocols (CON and RWU40). Significant differences are indicated by asterisks ($p < 0.05$).

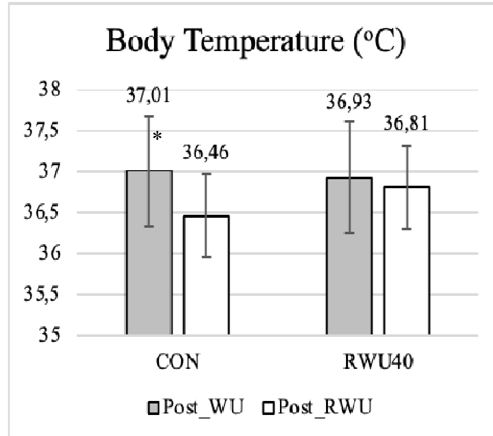


Figure 4: Means of Body Temperature for post-WU and post-RWU for the two protocols (CON and RWU40). Significant differences are indicated by asterisks ($p < 0.05$).

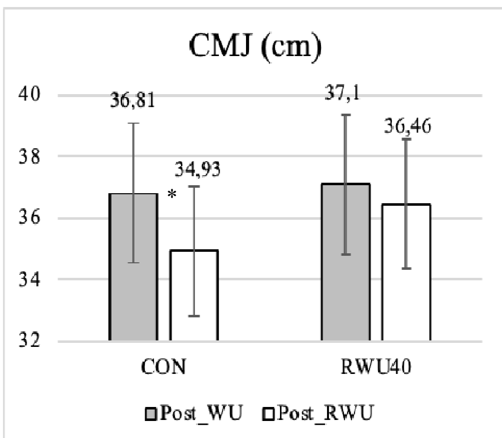


Figure 5: Means of CMJ for post-WU and post-RWU for the two protocols (CON and RWU40). Significant differences are indicated by asterisks ($p < 0.05$).

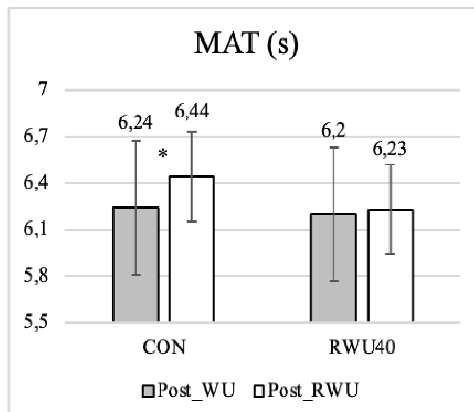


Figure 6: Means of MAT for post-WU and post-RWU for the two protocols (CON and RWU40). Significant differences are indicated by asterisks ($p < 0.05$).

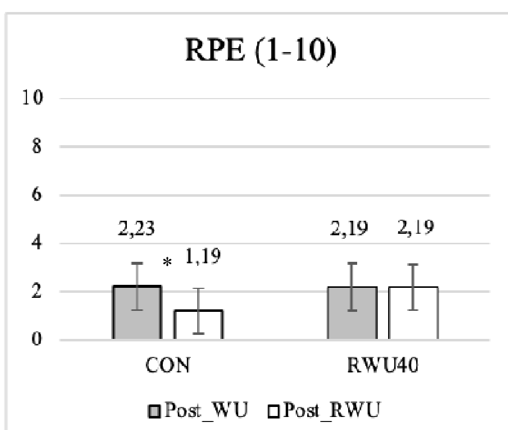


Figure 7: Means of RPE for post-WU and post-RWU for the two protocols (CON and RWU40). Significant differences are indicated by asterisks

Discussion

The major findings indicated that athletes' CMJ performance was reduced by 5.1% in the re-entry phase following the 15-min passive rest, while it was reduced by only 1.72% after RWU40. A similar trend was observed in MAT, where the time was increased by 3.13% after passive rest, while it increased by 0.48% after RWU40. Therefore, our hypothesis that a RWU protocol - permitted to be game applied - on a cycle ergometer at 40% VO_2max of each athlete may have a positive effect on jump and change of direction performance in semi-professional basketball players in comparison to passive rest is confirmed.

Previous RWU studies in basketball have utilized protocols during HT (González-Devesa et al., 2023, Pociūnas et al., 2018) where coaches may implement any type of RWU without game rule restrictions; these studies used different RWU protocols such as shooting wheel plus bouncing compared to traditional shooting (González-Devesa et al., 2023) which proved to be ineffective, and different aerobic protocols with or without post-activation performance enhancement (PAPE) activities (Pociūnas et al., 2018), reporting positive effects on performance only for the RWU plus PAPE. Only one study has examined RWU during a basketball game (Alberti et al., 2014) and tested the effect of various RWU protocols on the performance of basketball players. This study suggested that any sitting RWU protocol using either tapping or isometric contractions cannot counterbalance the performance impairment that resting on the bench has previously caused, highlighting the need to form RWU protocols that can be applied during game conditions without violating the FIBA rule restrictions.

To date, the cycle ergometer has been used as a RWU tool in healthy men (Yanaoka et al., 2018a, Yanaoka et al., 2018b; Yanaoka et al., 2020, Yamashita & Umemura, 2022). Relative performance assessments primarily focused on cycling sprints rather than running and jumping performances. RWU protocols, such as 7-min and/or 3-min at 70%HRmax, 3-min at 30% or 60% VO_2max, 1-min at 90% VO_2max, and 3 x 3s maximal effort with 27s rest, were previously applied during HT, resulting in improved performance in the Cycling Sprint compared with traditional passive halftime practices. Although these studies have investigated the effect of RWU, none have used team sports athletes as participants. To our knowledge, this is the first study in which the RWU protocol is performed on a cycle ergometer - which is allowed to be used during a basketball game according to FIBA rules (FIBA, 2023) - and the performance variables measured are crucial game components, such CMJ and MAT.

In the present study, the CMJ performance of basketball players who passively rested for 15 min decreased by 5.1%, while when they were engaged in RWU40, the loss was reduced to 1.72%. These results are in line with those of recent studies where the decline in CMJ performance varied across conditions. Christaras et al. (2023) reported a 13.2% CMJ decline in passive rest and a 7.3% CMJ decline after a 3-min active RWU, including running, skipping and jumping, in soccer players. Edholm et al. (2015) found a smaller CMJ reduction (7.6% in CON and 3.1% in RWU) after a 7-min low-intensity RWU involving jogging and calisthenics. Lovell et al. (2013) observed lower CMJ in the CON group than in the Whole-Body Vibration ($p = .031$) and Intermittent Agility Exercise ($p = .002$) groups. Conversely, Fashioni et al. (2020) noted improved jumping (SJ and CMJ) after a 3-min RWU incorporating body weight, ballistic, and plyometric exercises. Varying methodologies and RWU protocols make direct result comparisons challenging, but all acknowledge the potential CMJ performance benefits of the RWU protocol. This underscores the effectiveness of our proposed protocol. Furthermore, considering that the WU influences joint fitness, the observed improvements in CMJ performance may stem from a reduction in joint stiffness induced by the applied RWU.

MAT performance was reduced by 3.13% after 15 min of passive rest in the present study, whereas this loss was attenuated after RWU40 to 0.48%. MAT, a key component of this study, emphasizes the expression of power across multiple directions. This is particularly relevant in basketball, where dynamic movement sequences frequently involve rapid changes in direction across various planes during gameplay (Scanlan et al., 2021). Despite the critical role of MAT in basketball performance, to our knowledge, no previous study has evaluated MAT performance following a RWU protocol in athletes. Changes in direction and agility are particularly important physical qualities in basketball, as aggressive directional changes occur throughout a game when athletes compete for positional advantages (Spiteri et al., 2015). In a relative soccer study, (Christaras et al., 2023) Illinois agility test performance decreased similarly in both conditions (3-min RWU: 1%; 15-min Rest: 1.4%) and a 7-min jogging RWU during the HT did not limit the decline in arrowhead agility test performance (Bang & Park, 2022). Comparing directly the results of the present study with the aforementioned is not feasible, as not only the distances of the tests differ (Illinois: 60m, Arrowhead: ˜35m, MAT: 20m), but also the type of RWU. Knowing that MAT is underpinned by power-related physical attributes (Scanlan et al., 2021), we may assume that RWU40 caused an acute power enhancement, which, in practice, was evident through increased MAT performance compared to the passive rest condition.

Temperature elevation is one of the main objectives of RWU, as muscle and core temperatures are correlated with athletic performance (Mohr et al., 2004). In the present study, basketball players experienced a 1.48% reduction in body temperature after a 15-min passive rest versus 0.33% following RWU40. Each decrease in temperature of 1°C is accompanied by a decrease in performance of 3% (Sargeant, 1987), whereas an increase of 1 °C in muscles can lead to a 2–5% improvement in muscle power (Racinais & Oksa, 2010). Decreased body temperature has been previously associated with sprint and jump performance decline in basketball players (Galazoulas et al., 2012) and sprint performance impairment in soccer players (Mohr et al., 2004). Hence, the decline in performance observed in CMJ and MAT after both CON and RWU40 may also be attributed to a relative decrease in body temperature.

The average temperature decrement of 1.48% in the CON condition resulted in 5.1% and 3.13% performance decline in CMJ and MAT, respectively. Conversely, the smaller performance reductions (1.72% in CMJ and 0.48% in MAT) after RWU40 compared with the control condition may be attributed to the smaller (0.33%) decrease in temperature.

HR was also significantly reduced in the present study after 15 min of passive rest (24.51%). This reduction was only 9.12% after RWU40, similar to previous studies (Yanaoka et al., 2018a, Yanaoka et al., 2018b; Yanaoka et al., 2020, Yamashita & Umemura, 2022). As HR has been used as an indirect indicator of oxygen supply to the muscles (DeLorey et al., 2004), we may assume that RWU40 facilitates an increased oxygen supply through more efficient functioning of the circulatory system (Bang & Park, 2022).

The RPE during the athletes' reintegration into activity was higher after RWU40 than after CON by 1 point (2.19 vs 1.19, respectively) on the ten-point scale of Borg. We consider this difference to be significant, but not sufficient, to negatively impact athlete performance. Similar results have been found in other studies, where RPE ratings were significantly higher immediately following the completion of RWU protocols (Yanaoka et al., 2018a; Fashioni et al., 2020; Yamashita & Umemura, 2022). RPE scores provide information regarding the fatigue that RWU40 may have caused. It is well accepted in PAPE protocols that fatigue fights the potentiation that a dynamic protocol, such as RWU40, may cause, and PAPE is evident only when fatigue withdraws (Blazevich & Babault, 2019).

One point on the RPE scale alongside the performance improvement indicated that the RWU40 protocol was both non-fatiguing and effective in enhancing performance. As recent studies have highlighted that PAPE protocols are not effective for all athletes (Blazevich & Babault, 2019), we may assume that the RWU40 applied in the current study was effective because it was designed on an individualized basis.

Although this study was designed to be easily applied during a basketball game, it is important to acknowledge certain limitations. First, the study included only semi-professional basketball players, limiting the generalizability of the findings to professional or elite athletes. Another limitation is that neither electromyographic activity, muscle temperature with a needle thermistor, nor direct force/power measures were assessed during the trials. This prevents the availability of crucial physiological response data that could offer valuable insights. Future research could be conducted with re-entering periods longer than 15 min, or by applying protocols of different intensities and durations. Additionally, studies involving different population groups, such as women or youth players, would be beneficial for investigating more effective protocols under specific conditions.

Conclusion

In conclusion, a 3-min moderate-intensity RWU applied on a cycle ergometer improved performance compared to a 15-min passive rest in semi-professional basketball players. The protocol used in the present study attenuated the performance decrements caused by passive rest, resulting in athletes reintegrating into physical activity with a higher level of readiness. All performance variables measured (HR, Body Temperature, CMJ, MAT and RPE) were enhanced for basketball players following a cycling RWU at 40%VO_2max compared to the CON condition of 15 min of passive rest.

Practical applications

These results are particularly significant for basketball, which relies on the muscle force and power output of the athletes. Although cycle ergometers have been placed behind team benches during games, there is a lack of scientific data regarding their use in RWU in the field of basketball. Coaches should implement a short RWU protocol immediately before athletes re-enter the game, as they should be prepared for optimal performance without needing a transitional phase to regain the benefits of WU. These protocols can help maintain players' physical readiness during extended rest periods, improve physical performance, and reduce the risk of injury.

The effectiveness of these protocols can be enhanced by ensuring that the exercises and drills are sufficiently challenging to activate the neuromuscular system and maintain the players' body temperature without causing excessive exertion. Finally, coaches should educate their players on the importance of RWU protocols.

Disclosure statement
The authors report there are no competing interests to declare.

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