ORIGINAL ARTICLE

Optimizing performance with a 1-minute high-intensity re-warm up protocol in basketball substitutes

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ABSTRACT

The aim of the study was to investigate whether a 1-minute high-intensity Re-Warm Up (RWU) protocol on a cycle ergometer could attenuate the negative effects of passive rest on basketball players' performance. Twelve semi-professional players completed two trials on consecutive days in a counterbalanced, randomized design with repeated measures. Following a structured warm-up (WU), the trials included: a) 15 minutes of passive rest (CON) and b) 13 minutes of passive rest, followed by 1 minute of cycling at 80% VO_{2max} and 1 minute of rest (RWU80). Post-WU and post-RWU measurements included countermovement jump (CMJ), modified agility t-test (MAT), heart rate (HR), body temperature (BT), rating of perceived exertion (RPE), and perceived readiness rating (PRR). CON group showed significant decreases in all variables, while RWU80 attenuated these losses in HR (p = .127), RPE (p = .058) and PRR (p = .236). Between the two post-RWU measurements, the RWU80 showed significantly improved results in MAT (p = .05) and HR (p < .001) and higher RPE (p = .002). Although statistically significant differences did not appear in all variables, the RWU80 led to greater readiness of the substitute players to enter the game com-pared to the 15 minutes of passive rest.
Keywords: Performance analysis, Basketball, Re-warm up, Body temperature, Sport performance, Countermovement jump, Modified agility t-test.

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INTRODUCTION

Warm-up (WU) routines play a crucial role in enhancing subsequent performance in both training and athletic competitions (Sumartiningsih et al., 2022). These routines aim to raise muscle temperature which is associated with improved jump height (Krčmár et al., 2016), enhanced range of motion (Bleakley & Costello, 2013) and sprint performance (De Sousa et al., 2018). Basketball teams apply different warm-up routines to optimize the sport performance (De Sousa et al., 2018) and mitigate the risk of sport-related injuries (Ding et al., 2022) of the athletes. The performance boost resulting from WU is often attributed to temperature-related mechanisms (McGowan et al., 2015), which in general enhance neuromuscular function (Lovell et al., 2007).

However, prolonged periods of rest for players seem to lead to decreases in performance. Halftime (HT) passive recovery negatively impacts second-half repeated-sprint ability in team sports (Russell et al., 2015). Inadequate player preparation diminishes game tempo, affecting their competitive advantage (Mohr et al., 2004). HT passive recovery results in 1.1°C and 2.0°C reductions in core and muscle temperatures (Mohr et al., 2004). In a later study, core temperature dropped by 0.97 ± 0.29°C at HT (Lovell et al., 2007). VO_2 levels return to rest within approximately 5 minutes (Özyener et al., 2001). Galazoulas et al. (2012) found that a 10-minute bench rest led to decreased countermovement jump (CMJ) (13%) and 20m sprint performance (4%), with a more pronounced decrease after a 40-minute rest (20% and 6%, respectively). Re-warm up (RWU) strategies have been proposed to protect against physiological changes and performance decreases induced by passive recovery during HT (Russell et al., 2015; Hammami et al., 2018; Silva et al., 2018; González-Devesa et al., 2021; Koutsouridis et al., 2023).

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 (González-Devesa et al., 2023). However, passive rest in basketball does not only exist during HT, but also during the game for substitute players. The time spent seated for the bench players can exceed 15 minutes (Alberti et al., 2014).

To our knowledge, only two researches have been conducted during a basketball game. In the study of Alberti et al. (2014), participants engaged in various seated activities (sitting, seated foot tapping, seated lower back mobilization), resulting an 8.48% reduction in jump height for all seated players after 20 minutes. However, 2-min activity is nearly sufficient to recover post-WU performance levels. In a recent study, Koutsouridis et al., (2024) found that a 3-min moderate-intensity RWU protocol performed on a cycle ergometer may diminish the negative effects of a 15-min passive rest on players' athletic performance.

Due to the lack of research on RWU protocols during basketball games, restrictions imposed by FIBA rules (2023) that prohibit any standing RWU activities during games, and the need for a shorter protocol than the one proposed by Koutsouridis et al. (2024), it is crucial to explore different RWU protocols with varying durations and intensities. Therefore, this study aimed to determine if a 1-minute high-intensity RWU protocol on a cycle ergometer could counteract the negative effects of passive rest on basketball players' physical abilities.

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 (Koutsouridis et al., 2024) that investigated the impact of a moderate-intensity cycling RWU on subsequent athletic performance. Utilizing an effect size (ES) of 1.0, an α-level of .05 and a power of 0.8

(Yanaoka et al., 2021), the analysis indicated that a minimum of 10 participants was required. The study involved 12 semi-professional basketball players, with an average age of 20.33 years (±1.30), whose characteristics are presented in Table 1. All participants signed a consent form after receiving clarifications about the aim, procedures and potential hazards of the study. All procedures were performed in accordance with the code of the local ethics committee and the Helsinki declaration.

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

	Min	Max	Mean	Std. Deviation
Age (years)	19	22	20.33	1.303
Training age	3	13	9.50	2.939
Trainings per week	2	6	3.75	1.215
Body Mass (kg)	70.8	90.5	82.18	5.887
Height (cm)	174.0	195.0	183.86	6.515
BMI (kg/m^2)	21.80	28.77	24.37	2.184
Body fat (%)	5.51	22.43	12.64	4.681
VO_{2max}	36.48	60.29	49.93	5.834
WATTmax	224	320	292.00	26.751
7.5% of BM (kg)	5.31	6.79	6.16	.442
Resting HR (bpm)	54	91	73.50	11.890

Note. BMI = Body Mass Index, bpm= beats per minute, HR = Heart Rate, VO_{2max} = Maximum Oxygen Uptake.

Experimental design

Participants completed two experimental sessions using a counterbalanced, randomized order and a repeated measures design, preceded by an initial visit for the assessment of their maximum oxygen uptake (VO_{2max}). The athletes performed a standard basketball WU and then engaged in one of two protocols. The first protocol involved 15 minutes of passive rest (CON), while the second consisted of 13 minutes of passive rest, 1 minute of cycling at 80% of VO_{2max} and 1 minute of recovery (RWU80). Variables were assessed at two time points: after the warm-up (post-WU) and after the RWU protocol (post-RWU). The variables were CMJ, Modified Agility T-test (MAT), HR, body temperature (BT), perceived exertion (RPE) and perceived readiness rating (PRR). The study's design is presented in Figure 1.

Participants were instructed to maintain their regular lifestyle, exercise and diet during the study. They recorded all meals and drinks consumed the day before each trial, replicating the same dietary intake in subsequent trials to ensure consistency. Alcohol and caffeine were avoided 24 hours before each experimental session. During the study, players had access to water *ad libitum.*

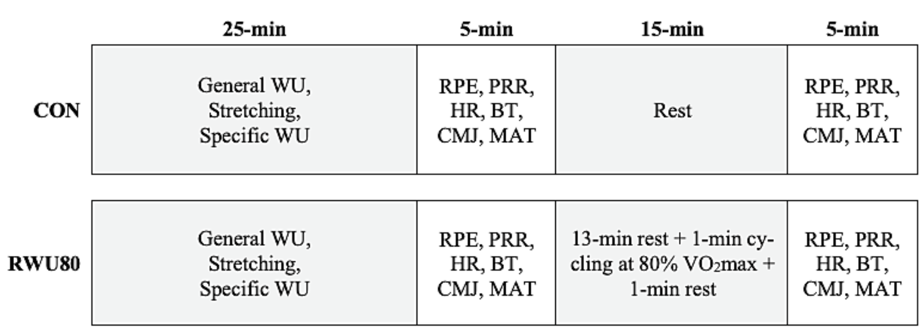

Figure 1. Summary of the study design.

Procedures

Participants received detailed instructions one week before conducting the study. Preliminary measurements (mass, height, body fat percentage, VO_{2max}) were performed during this period. Additionally, participants underwent multiple trials to familiarize themselves with the test procedures. Subsequently, the measurements were conducted on two separate days with a 48-hour difference. To minimize circadian effects, all measurements for each athlete were taken at the same time of day, with a maximum 15-minute difference. The average temperature and humidity in the indoor basketball court were 18.2°C ± 1.3°C and 43.2% ± 8.5%, respectively.

The athletes were randomly divided into two groups. On the first day, one group executed the CON condition and the other group the RWU80, while on the second day the opposite. At the beginning of each day, athletes underwent a typical basketball WU, as in Galazoulas et al., (2012). Subsequently, they underwent post-WU measurements to assess their optimal performance. Afterward, they followed one of the two protocols and then underwent the same measurements again (post-RWU).

Measurements

VO_{2max} was assessed through a graded exercise test on a cycle ergometer, with participants maintaining a consistent cycling cadence of 80 revolutions per minute (rpm). The protocol began with a workload of 1.2 kg (96W) for 3 minutes, followed by an increase to 1.9 kg (152W) for an additional 3 minutes. Workload continued to increase by 0.3 kg per minute until voluntary exhaustion. Oxygen uptake (VO_2) was measured breath-by-breath using an automatic gas analyser (AE-310s, Minato Medical Science, Japan), averaged over 15-second intervals. VO_{2max} was calculated when two of the following three conditions were met: 1) VO_2 levelling off, 2) HR exceeding 90% of the maximum rate (220 - age), and 3) respiratory exchange ratio exceeding 1.05.

Body temperature was assessed using an infrared ear thermometer (TotiFar CT-30DX, OST, Jsinchu, Taiwan), as in the study by Galazoulas et al., (2012). HR data was collected utilizing the Polar Team Pro system (Kempele, Finland). Heart rate was collected at three time points for all participants (pre-WU, post-WU, post-RWU) through a transmitter worn by the athletes on a chest strap.

The CMJ was implemented for assessing participants' vertical jump and leg explosive power. Athletes performed three consecutive CMJ with an interval of 30 seconds. The OptojumpTM system (Microgate, Bolzano, Italy) was utilized for the recording the jumps and the highest jump was used for analysis. A Pearson correlation analysis revealed robust consistency across the three CMJ measurements ($r > 0.945$), showing a high level of measurement reliability.

MAT was chosen to assess athletes' performance, focusing on power-related physical abilities. The MAT evaluates multidirectional power expression, aligning well with basketball's dynamic movement patterns involving rapid changes in direction across various planes (Scanlan et al., 2021). All trials were timed with the 0.001s precision Witty photocell system (Microgate, Bolzano, Italy). The test procedure followed the format described in Scanlan et al., (2021). Participants performed the test once, as repeating the test would affect the acute effects of the RWU protocol.

Perceived exertion was evaluated through the 10-point scale of Borg (1982), while perceived readiness was assessed using Karu et al.'s (2000) 5-point scale.

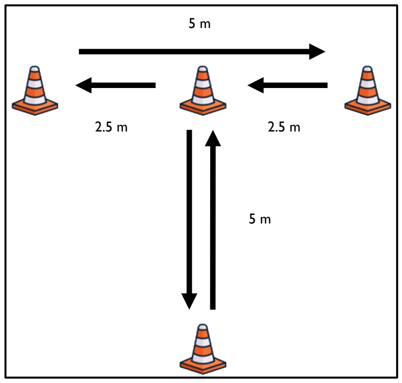

Figure 2. Modified Agility T-test.

Statistical analysis

The statistical analysis was performed utilizing SPSS computer software (version 28.0, SPSS Japan Inc., Tokyo, Japan). Mean ± SD values are presented. To verify the model's appropriateness, the assumptions of the general linear model (GLM) were evaluated. A Two-Way Repeated Measures test (2 x 2, Time x Protocol) was used for comparing differences between measurements of times and protocols. Post-hoc multiple comparisons were conducted using the Bonferroni method when significant interactions and trial effects were found. The statistical significance level was set at $p < .05$. Additionally, partial eta squared values were computed to assess the effect size for all main effects and interactions, categorized as small (0.01 – 0.059), moderate (0.06 – 0.137) and large (>0.138) (Richardson, 2011). Cohen's d effect sizes with a 95% confidence interval were reported, where values exceeding 2.0 indicated a very large effect, 1.2 – 2.0 a large effect, 0.6 – 1.2 a moderate effect, 0.2 – 0.6 a small effect and 0.19 or lower a trivial effect (Hopkins et al., 2009).

RESULTS

The study aimed to investigate potential differences within each group between post-WU and post-RWU measurements, as well as differences between the two post-RWU measurements. Table 2 presents the means, standard deviations, percentage differences (PD), p-values, and Cohen's d effect sizes for all measurements.

The results of the two-way repeated measures ANOVA for CMJ revealed a significant main effect of Time (F = 30.993, $p < .001$, $\eta_p^2 = .738$). Notably, the difference between post-WU and post-RWU measurements reached significance in both CON and RWU80 conditions (CON: $p < .001$, d = 1.630, PD = -4.98%; RWU80: $p = .005$, d = 1.007, PD = -4.32%). Even though the CMJ was higher in RWU80 than in CON in post-RWU measurements, the difference was not statistically significant. As for the MAT, there was a significant main effect both for Time (F = 18.052, $p = .001$, $\eta_p^2 = .621$) and for Protocol (F = 5.451, $p = .040$, $\eta_p^2 = .331$). The difference between post-WU and post-RWU measurements was significant in both conditions (CON: $p = .039$, d = .674, PD = 3.19%; RWU80: $p = .008$, d = .936, PD = 2.45%). MAT performance was higher in RWU80 than in CON post-RWU ($p = .05$, d = .631, PD = 2.94).

Significant effects were found in HR for Time, Protocol and their interaction in the two-way repeated measures analysis (F = 83.076, $p < .001$, $\eta_p^2 = .883$). HR was significantly decreased in CON group ($p < .001$, d = 2.403, PD = -23.42%), however, this decline was reversed in RWU80. The difference between the two post-RWU measurements was also statistically significant ($p < .001$, d = 2.732, PD = 37.72%). With regards to BT, there was a significant main effect of Time (F = 36.675, $p < .001$, $\eta_p^2 = .774$). Under both conditions, the decrease in temperature between post-RWU and post-WU measurements was statistically significant (CON: $p < .001$, d = 1.329, PD = -1.38%; RWU80: $p < .001$, d = 1.322, PD = -1.00%).

Table 2. Statistical results.

Variable	Group	Post-WU	Post-RWU	Mean Diff.	PD	Sig.	Cohen's d
CMJ (cm)	Control	36.92 ± 2.20	35.08 ± 2.00	-1.84	-4.98%	<.001*	1.630
	RWU80	37.03 ± 2.92	35.43 ± 2.31	-1.60	-4.32%	.005*	1.007
	Comparison between postRWU measurements:			.35	1.00%	.615	.149
MAT (s)	Control	6.27 ± .41	6.47 ± .28	.20	3.19%	.039*	0.674
	RWU80	6.13 ± .38	6.28 ± .36	.15	2.45%	.008*	0.936
	Comparison between postRWU measurements:			.19	2.94%	.050*	.631
HR (bpm)	Control	128.08 ± 15.10	98.08 ± 12.56	-30.00	-23.42%	<.001*	2.403
	RWU80	128.25 ± 13.87	135.08 ± 10.48	6.83	5.33%	.127	0.477
	Comparison between postRWU measurements:			37.00	37.72%	<.001*	2.732
Body temp. (°C)	Control	37.00 ± .70	36.49 ± .41	-.51	-1.38%	<.001*	1.329
	RWU80	36.98 ± .44	36.61 ± .41	-.37	-1.00%	<.001*	1.322
	Comparison between postRWU measurements:			.12	0.33%	.374	.267
Perceived exertion	Control	2.333 ± .91	1.208 ± .81	-1.13	-48.22%	.003*	1.122
	RWU80	2.417 ± 1.16	3.042 ± 1.44	.63	25.86%	.058	.610
	Comparison between postRWU measurements:			1.83	151.82%	.002*	1.136
Perceived readiness	Control	4.042 ± .78	3.271 ± .89	-.77	-19.07%	.002*	1.151
	RWU80	3.875 ± .56	3.625 ± .46	-.25	-6.45%	.236	.362
	Comparison between postRWU measurements:			.35	10.82%	.252	.349

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

Significant effect for Time x Protocol interaction was found in RPE between the CON and the RWU80 group (F = 21.560, $p < .001$, $\eta_p^2 = .662$). Under the CON condition, RPE was significantly reduced in post-RWU compared to post-WU measurement ($p = .003$, d = 1.122, PD = -48.22%), whereas this was not observed in RWU80. Additionally, comparing the two post-RWU measurements, RPE was significantly increased in the RWU80 ($p = .002$, d = 1.136, PD = 151.82%). With regards to PRR, there was a significant main effect of Time (F = 10.741, $p = .007$, $\eta_p^2 = .494$). Significant difference was observed between post-WU and post-RWU in CON ($p = .002$, d = 1.151, PD = -19.07%) but not in RWU80.

DISCUSSION

The major findings indicated that performance decrements were smaller under the RWU80 compared to the CON condition, whilst the differences between post-WU and post-RWU measurements remained statistically significant in most variables in both conditions. The athletes' performance in CMJ after RWU80 was slightly better compared to CON; However, the decrease in performance was statistically significant in both groups. On the contrary, performance in MAT during post-RWU measurements was significantly better after RWU80. Considering all the variables included in this study, our findings confirm that an 80% VO_{2max} RWU protocol on a cycle ergometer positively influences the subsequent performance of basketball players compared to a 15-minute passive rest. However, the protocol's intensity might lead to fatigue, explaining the non-significant improvements in some variables.

To our knowledge, only one study has investigated a RWU protocol on cycle ergometer in basketball players (Koutsouridis et al., 2024). Another study conducted during the game (Alberti et al., 2014), albeit without a cycle ergometer, found that tapping or isometric contractions cannot prevent performance losses caused by passive rest. Other studies in basketball have been conducted during HT with protocols that are not applicable during the game (González-Devesa et al., 2023, Pociunas et al., 2018). Therefore, more research is needed to establish the scientific background, allowing athletes to implement protocols compliant with regulations of FIBA (2023).

In the current study, the decline in CMJ performance among basketball players who underwent passive rest for 15 minutes was 4.98% with large effect size. In contrast, when they participated in RWU80, the decrease was mitigated to 4.32%, though the difference is not statistically significant and the effect size is moderate. The corresponding decrease in CMJ performance in the study by Koutsouridis et al., (2024), following a 3-minute RWU at 40% of VO_{2max}, was only 1.72%. This indicates that a protocol of slightly longer duration with moderate intensity is more suitable before the athlete's engagement in the game. Several investigations during HT in soccer players demonstrated notable reductions in CMJ performance, with declines of 13.2% (Christaras et al., 2023), 7.6% (Edholm et al., 2015) and 6.76% (Fashioni et al., 2020) reported. The results of the RWU methods from the aforementioned studies were applied during HT on a soccer field (running, skipping, jumping, calisthenics, whole-body vibration, intermittent agility exercise). Therefore, they cannot be implemented during basketball games, nor can they be compared with the findings of the present study.

MAT performance decreased by 3.19% following 15 minutes of passive rest. However, this decline attenuated to 2.45% after RWU80, indicating moderate effect sizes in both conditions. Additionally, the RWU80 measurement was significantly better than the CON measurement between the two post-RWU assessments. In comparison, the RWU40 by Koutsouridis et al. (2024) mitigated the losses from passive rest more effectively, as the corresponding reduction was only 0.48%. Previous studies have frequently indicated that basketball players with better performance in agility tests are more successful in terms of competitive achievement (Versic et al., 2021). Change of direction and agility stand out as crucial physical attributes in basketball, given the frequent occurrence of dynamic directional changes during a game when athletes compete for positional advantage (Spiteri et al., 2015). However, to our knowledge, there is no other research investigating an agility test after RWU in basketball players.

In the present study, basketball players experienced a reduction in BT of 1.38% (0.51ºC) after a 15-minute passive rest, compared to 1.00% (0.37ºC) following RWU80, both reaching significant levels of difference and indicating large effect sizes. The observed decreases surpassed the results of Sargeant (1987) which indicated that each 1º C decrease in temperature is linked to a 3% decline in performance. The average temperature decrement of half a degree (0.5°C) in the CON condition resulted in approximately 5% and 3.2% performance decline in CMJ and MAT, respectively. Conversely, the smaller performance reductions (4.32% in CMJ and 2.45% in MAT) after RWU80 compared to the control condition may be attributed to the smaller (0.37°C) decrease in temperature. In Koutsouridis et al.'s study (2024), a longer 3-minute RWU at moderate intensity resulted in improved athlete performance, with a smaller temperature decrease (0.12°C) and reduced performance decrements (1.72% in CMJ and 0.48% in MAT). These results support previous research associating body temperature decrease with declines in sprint and jump performance in basketball players (Galazoulas et al., 2012) and sprint performance in soccer players (Mohr et al., 2004). Additionally, the findings are consistent with Galazoulas et al. (2012), suggesting that 'cooling-down' may have a more severe impact on jumping rather than running performance and with Mohr et al. (2004), concluding that temperature elevation is correlated with athletic performance.

There was a significant decrease in HR following a 15-min passive rest (23.42%). This result was completely reversed after RWU80 as the HR was increased compared to the postWU measurement by 5.33%. Any protocol implemented in previous studies has led to increased HR compared to passive rest (Yanaoka et al., 2018a; 2018b; 2020; Yamashita & Umemura, 2022). Following initial increased HR, soccer players experience reduced HR during the first seven minutes of the second half compared to the passive rest condition. This phenomenon was attributed to the enhanced efficiency of the circulatory system which facilitated the transportation of gases, nutrients for energy production and removal of derivatives of biochemical reactions (Bang and Park, 2022). However, the small performance improvements in this study and the increased HR compared to post-WU levels indicated that the high intensity of the protocol did not have such a positive impact, as also reflected in the athletes' subjective measurements.

Following RWU, the RPE was significantly higher for the RWU80 protocol compared to the CON condition, with a differential of 1.83 points, representing a 151.82% increase. During reintegration into activity, the RPE for the RWU40 protocol was also elevated in comparison to the CON, showing a 1-point increase, with values of 2.19 versus 1.19 on the ten-point Borg scale (1982), as found in a similar study (Koutsouridis et al., 2024). These findings indicate that both RWU protocols resulted in higher perceived exertion than the CON, with the RWU80 protocol leading to a greater exertion. These findings align with the accepted understanding within Post-Activation Performance Enhancement (PAPE) protocols, where fatigue counteracts the potentiation effects that dynamic protocols may induce. According to Blazevich and Babault (2019), PAPE is observable only when fatigue diminishes. Additionally, in comparing post-RWU to post-WU conditions, RWU80 resulted in a performance decrement of 4.32% in the CMJ and 2.45% in the MAT. In contrast, RWU40 achieved smaller losses of 1.72% in CMJ and 0.48% in MAT. These results suggest that RWU80 was a sufficiently intense protocol to induce significant fatigue in athletes. Nonetheless, despite this fatigue, athletes were better prepared post RWU80 compared to 15 minutes of passive rest.

The above conclusion can be supported by the results of perceived readiness, where, to our knowledge, no study has examined it following a RWU protocol in any sport. Readiness significantly decreased in the CON condition, whereas in RWU80, the loss was not statistically significant. Comparing the two post-RWU measurements, athletes felt 10.82% more prepared when they underwent the RWU80 protocol compared to passive rest. Readiness results were further supported by athletes' performance outcomes and physiological factors, where all metrics were improved in RWU80 compared to CON.

This study had limitations regarding the measurement of muscle temperature and electromyographic activity. These parameters were not assessed during the trials, which limited the availability of crucial physiological data. Future research could investigate scenarios where players participate in game, then sit on the bench for an extended period before re-entering, allowing for an evaluation of the effectiveness of a RWU during their return. Such studies would offer valuable insights into optimizing performance strategies during extended periods of rest within games.

Practical applications

Despite the increasing placement of cycle ergometers behind team benches during games, there is a lack of scientific data regarding their use in RWU. Coaches can incorporate a short RWU protocol right before athletes' re-entering the game ensuring optimal performance. The results of the present study indicate that coaches have the flexibility to adapt the intensity and duration of the RWU based on the available time for its implementation. The RWU protocol need to be challenging enough in order to activate the neuromuscular system and sustain the players' body temperature, but simultaneously avoiding excessive fatigue.

CONCLUSIONS

A 1-min high-intensity RWU implemented on a cycle ergometer demonstrated a performance improvement in semi-professional basketball players when compared to a 15-min passive rest. The utilized protocol in this study mitigated the performance declines associated with passive rest, leading to athletes returning to physical activity at an elevated readiness level. All measured performance variables (HR, Body Temperature, CMJ, MAT, RPE, and perceived readiness) showed enhancement for basketball players following a 1-minute cycling RWU at 80% VO_{2max}, as compared to the 15-min control condition of passive rest.

AUTHOR CONTRIBUTIONS

Christos Koutsouridis conducted the literature review, developed the experimental design, performed the measurements and the data analysis and drafted the original manuscript. Christos Galazoulas contributed to the conceptualization and the experimental design, and together with Vasiliki Manou and Nikolaos Stavropoulos, provided supervision and project oversight. Dimos I. Prantsidis contributed to the visualization and the final review of the manuscript. All authors reviewed and approved the final version of the article.

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No potential conflict of interest was reported by the authors.

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