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Effects of a Short Half-Time Re-Warm-Up Program on Matches Running Performance and Fitness Test Performance of Male Elite Youth Soccer Players

Michail Christaras, Yiannis Michailidis *, Athanasios Mandroukas, Lazaros Vardakis, Kosmas Christoulas and Thomas Metaxas

Laboratory of Evaluation of Human Biological Performance, Department of Physical Education and Sports Science, Aristotle University of Thessaloniki, 57001 Thessaloniki, Greece

* Correspondence: ioannimd@phed.auth.gr; Tel.: +30-231-099-2233

Abstract: The aim of the study was to investigate the effect of a half-time short re-warm-up (RW) strategy on the performance of young soccer players in tests of physical abilities and running performance during matches. Twenty-three players (under 17) participated in the study. Body temperature, 10 m sprint, 30 m sprint, the Illinois agility test, countermovement jump (CMJ), and squat jump (SJ) were measured, immediately post-warm-up. Then in one condition, the tests were repeated after a passive rest, and in the other condition, after a 12 min passive rest and 3 min RW. Furthermore, the RW was applied at half-time of two of the four matches where the running performance was measured in the first quarter of the two halves. The results showed that the two conditions differed significantly in the 10 m sprint and CMJ performances ($p < 0.001$ and $p = 0.049$, respectively). After the passive rest, a significant decrease in body temperature and performance in SJ was observed ($p < 0.001$ for both). No other differences were observed. In conclusion, the short RW program can limit the decrement in performance in power tests such as sprints and jumps.

Keywords: jump performance; sprint performance; agility; re-warm-up; half-time; running performance during match

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1. Introduction

The warm-up precedes each soccer match and is the first part of every training session concerning all ages and levels. The goal of warming up is the progressive preparation of the organism so that it can perform maximally and reduce the likelihood of developing muscle injury [1]. The above beneficial effects of the warm-up for soccer players are due to an increase in body temperature, more efficient functioning of the cardiorespiratory system, increased neuromuscular coordination, and improved mental and spiritual readiness [2,3]. The benefits of the warm-up in performance are well established for both adult athletes [2,3] and young athletes [4].

A soccer match consists of two halves of 45 min separated by a break of 15 min. This respite is used to mentally charge the players, hydrate them, and give them tactical instructions so that they are more effective during the second half. However, during this 15 min break, the muscle temperature decreases [2], which can have negative effects not only on the performance of the players in the initial minutes of the second half but also on the likelihood of injuries [5]. This fact is supported by studies that show that soccer players in the first 10–15 min of the second half run fewer meters and with less intensity compared to the corresponding interval of the first half. In a recent study, Russell et al. (2016) [6] reported that, regarding Premier League players, in the first 15 min of the second half, the number of decelerations, the distance covered at a high intensity, and the running pace of the players differed significantly from the corresponding values of the first 15 min of the match. With regard to developmental ages, there are no studies to indicate the change in running performance in the initial minutes of the second half in comparison with the first half. However, there are studies that have investigated the change in running performance between the two halves. In these studies, some observed a decrease in performance [7–9], others found no differences [10,11], and others noticed an increase in performance [12,13]. This decrease in performance in the first few minutes after half-time can be attributed to the limited recovery from the first-half effort, the lack of preparation for the second half, and other factors such as internal motivation and tactical instructions.

Because this phenomenon has been observed by sports scientists for years, attempts have been made to limit these negative effects. For this purpose, programs are proposed that can be implemented in order to limit the decrease in body temperature and performance in general as described in a recent review [14]. More specifically, re-warm-up programs have been used that include cycling, soccer actions, running, agility, etc. [2,15–18]. Mohr et al. (2004) [2] studied the beneficial effect of a 7 min re-warm-up at half-time on sprint performance during soccer matches. In a more recent study, Abade et al. (2017) [15] compared the effects of different re-warm-up programs on the physical performance of soccer players. From the above studies, we understand that there is a great variety of exercises used for this purpose. They also vary in methodology, with some studies assessing the running performance of soccer players during real soccer matches [2,16] while others evaluated performance in simulation tests [18,19]. In a study carried out on soccer players of developmental age [17], they observed that the implementation of active re-warm-up programs at half-time limited the decrement in endurance performance during the second half. However, it should be mentioned that the study evaluated running performance in a particular running drill and not in a real soccer match.

In previous studies, it has been reported that only 58% of Premier League and Championship coaches implement such programs on the pitch or in specially designated areas and 63% say the main reason they do not use them is lack of time [20]. Therefore, various programs that were suggested to last approximately seven minutes seemed to be effective in maintaining body temperature and performance on various fitness tests. However, they were not realistic as they took a great deal of time. As a result, coaches did not apply them. Moreover, studies have investigated the effect of shorter programs (<7 min) [21]. From the review of the literature, it seems that studies investigating such warm-up programs are limited [21].

Thus, the purpose of the study was to investigate the effect of a very short (three-minute) re-warm-up program on the performance of high-level young soccer players in fitness tests and their running performance during soccer league matches. Considering previous studies that have reported maintaining the performance of football players after a re-warm-up compared to passive rest, we assume that both the running performance of the players during the matches and their performance in the fitness tests will be higher after the implementation of the re-warm-up program in comparison to the passive rest.

2. Methods

2.1. Participants

To find participants, we approached a large soccer club in our region. The study involved 23 high-level young (aged under 17, U17) soccer players who voluntarily agreed to participate. The players had an average training age of 10 years, trained four times a week, and competed in one match every weekend. They participate in the championship of academies of national professional clubs. The characteristics of the participants are presented in Table 1. The participants and their parents, after being presented with the benefits and possible risks of participation in the study, signed consent forms. All procedures were in accordance with the Code of Ethics of the Aristotle University of Thessaloniki and the Helsinki declaration.

Table 1. Participants' physical characteristics.

Variable	Mean ± SD
Age (years)	16.5 ± 0.4
Training age (years)	10.2 ± 1.1
Height (cm)	171 ± 8
Weight (kg)	67.1 ± 6.6
Body fat (%)	12.3 ± 2.7

2.2. Study Design

The design of the study is shown in Figure 1. The two conditions concerned the effect of the re-warm-up on fitness tests and the running performance of the players in the first 15 min of the second half in U17 league matches. In the first condition, the participants warmed up on a soccer field and, immediately after that, body temperature and fitness tests were conducted (10 m and 30 m sprint, countermovement jump—CMJ, squat jump—SJ, and the Illinois agility test). Then they rested for 15 min (passive) and repeated the measurements (Condition passive: P (15 min)). In the second condition, they followed the same procedure but rested passively for 12 min, and the remaining condition implemented a re-warm-up program (condition re-warm-up: 3 min RW). The soccer players also played 4 league matches. In two of them, the same re-warm-up program was applied at half-time, and in the other two, they followed the usual passive rest at half-time. During resting, the players remained seated on the bench and had access to water ad libitum.

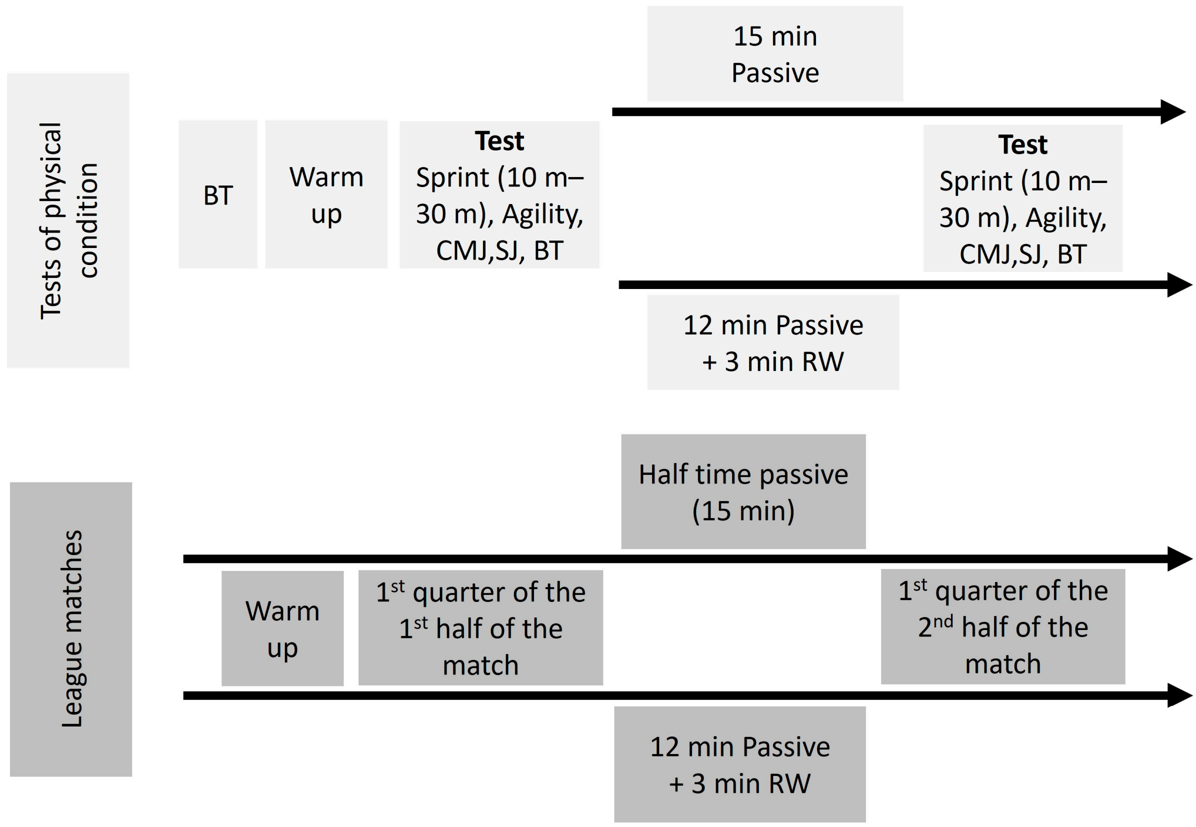

Figure 1. Study design. BT, body temperature; CMJ, countermovement jump; SJ, squat jump; RW, re-warm-up.

2.3. Experimental Protocol

A randomized crossover design was applied in the study. The players were assigned to the two conditions (P (15 min) and 3 min RW) related to the fitness tests and the matches in random order. The players warmed up for 25 min using the warm-up used by the team before a match. In the conditions with the fitness tests, the physical temperature of the players was recorded before the warm-up, immediately after, and 15 min after passive rest or the application of the re-warm-up. Fitness tests were conducted immediately after the end of the warm-up and after the 15 min break with passive rest or after the re-warm-up. The re-warm-up program is presented in Table 2. In the matches, the running performance of the players was recorded using GPS monitoring (GPS, 10 Hz Polar Team Pro, Kempele, Finland). The temperature of the body was measured in the ear with an infrared ear thermometer (TotiFar CT-30DX, OST, Jsinchu, Taiwan). The ambient temperature was 12–14 °C throughout the experimental process.

Table 2. Exercises of the re-warm-up program.

Exercise	Reps	Rest
Running at 70–90% of max speed for 30 m	1	~30 s
Skipping for 20 m	1	~30 s
3 jumps with knees to chest and sprint 30 m	1	~40 s
Sprint and change of direction 180° every 5 m (total 20 m)	1	~40 s

2.4. *Anthropometric Measurements*

Body weight and height were measured with an accuracy of 0.1 kg and 0.1 cm, with the participants wearing their underwear and without shoes (Seca 220e, Hamburg, Germany). The percentage of body fat was calculated by measuring four skinfolds (biceps, triceps, suprailiac, and subscapular) on the right side of the body, and the percentage of body fat was estimated with the equation proposed by Siri [22].

2.5. *Jumps*

Two tests were used to assess jumping ability: (a) Countermovement jump (CMJ) and squat jump (SJ). The hands were placed on the waist in both tests. In the CMJ, the soccer players would bend their knees at a 90° angle and jump as high as they could. In the SJ, from a seated position (knees at 90°), the soccer players jumped as high as they could without prior pretension (movement of the body downwards). Two attempts were made, and we used the best performance. Performance was measured using the electronic leap mat Chronojump from Boscosystem (Chronojump, Boscosystem, Barcelona, Spain).

2.6. *Acceleration—Speed*

To assess acceleration and speed, sprint tests of 10 m and 30 m were used. From an upright position 0.3 m behind the starting line, the players ran as fast as they could over a distance of 30 m. Photocell gates (Microgate, Bolzano, Italy) were placed at 10 m and 30 m at hip height to avoid receiving incorrect signals from the movement of the limbs (hands). They performed two attempts, and the shortest time was used for statistical analysis.

2.7. *Agility*

The Illinois agility test was used to assess agility. Soccer players from A sprinted to B and from there to C. They slalommed to D and returned in the same way to C. From there they sprinted to E and from E to F. The distance was 60 m, and photocell gates (Microgate, Bolzano, Italy) to record the time were placed at the start (A) and finish (F). A description of the test is shown in Figure 2.

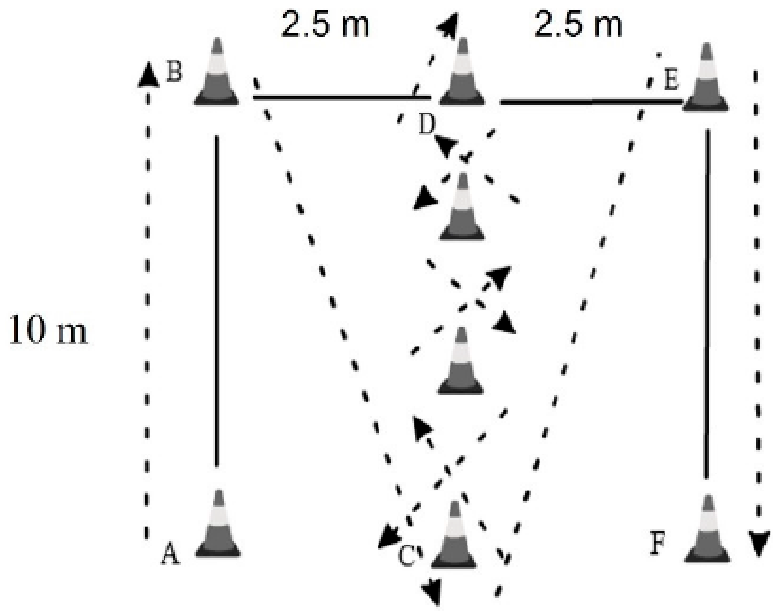

Figure 2. Illinois agility test.

2.8. Internal Load

HR was recorded in real time with the use of a Polar Team Pro (Kempele, Finland) during soccer matches.

2.9. External Load

The Global Positioning System (GPS, 10 Hz Polar Team Pro, Kempele, Finland) was used to record the external load. The variables recorded were total distance (TD), distance/min (m/min), the distance covered in four speed zones (Distance Speed: z1: 7.00–10.99 km/h; z2: 11.00–14.99 km/h; z3: 15.00–18.99 km/h; z4: >19.00 km/h), the total number of decelerations (NoDec 5.00–3.00 m/s^2), and also the total number of accelerations (NoAcc 3.00–5.00 m/s^2). The system's validity and reliability were described in a previous study [23].

2.10. Statistical Analysis

The sample size was estimated using G*Power 3.1 and the data from a previous study that investigated the re-warm-up effects on exercise performance [24]. A sample size of ≥20 participants was required in order to detect improvements in exercise performance with a power of 80% and an alpha level of 5%. The results are presented as the mean ± standard deviation (mean ± SD) or the mean and 95% confidence interval. Initially, a check of the normal distribution of the data was carried out using the Shapiro–Wilks test and it was found that the use of non-parametric methods of analysis was not needed. Thus, changes in body temperature and fitness tests were analyzed with a one-way analysis of variance (ANOVA) with repeated measures. To compare the two conditions (P (15 min) and 3 min RW) in the running performance in the matches at two halves, a two-way ANOVA with repeated measurements was used. Significant differences were checked with the Bonferroni test. The level of statistical significance was set at $p < 0.05$. Partial eta squared values were also reported, with these classified as small (0.01–0.059), moderate (0.06–0.137), and large (>0.138) [25].

3. Results

The results showed that the initial body temperature differed from the temperature after the warm-up ($p < 0.001$) and after RW ($p = 0.007$). The temperature after warming up differed from the temperature after passive rest ($p < 0.001$). Temperature changes are shown in Figure 3.

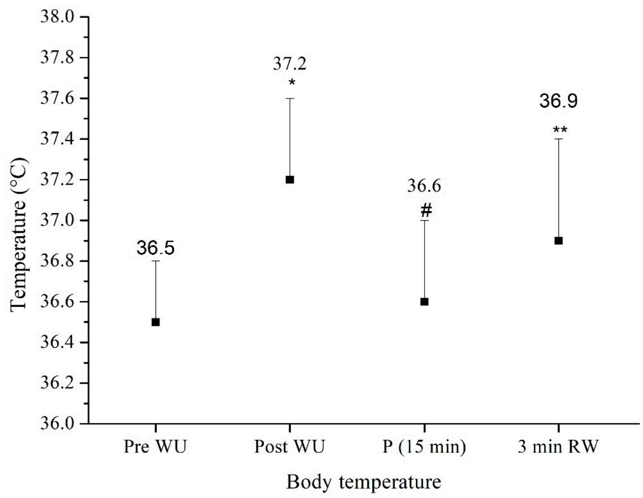

Figure 3. Changes in body temperature. Mean value and standard deviation are presented; * denotes significant difference with Pre WU at level $p < 0.001$; ** denotes significant difference with Pre WU at level $p < 0.01$; # denotes significant difference with Post WU at level $p < 0.001$; WU, warm-up; P (15 min), passive rest for 15 min; 3 min RW, 12 min passive rest and 3 min re-warm-up.

The results for CMJ showed that the performance immediately after warming up differed significantly in both conditions (P (15 min): $p < 0.001$; 3 min RW: $p = 0.01$). The two conditions also differed from each other ($p = 0.049$, $\eta^2 = 0.575$). Significant differences were also observed in the SJ test where the performance immediately after the warm-up differed from that after the passive rest ($p < 0.001$, $\eta^2 = 0.539$). In the condition in which RW was applied, the decrease was 5.2% as opposed to the control condition (p (15 min)) where the decrease reached 8.9%. Changes in jump performance are shown in Figure 4.

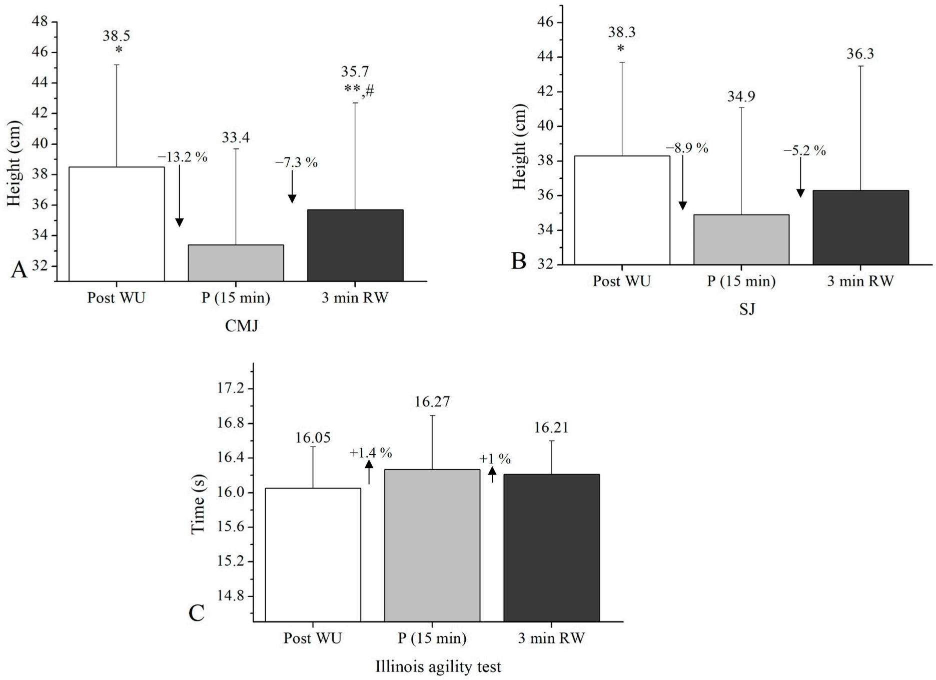

Figure 4. (**A**) CMJ performance test, (**B**) SJ performance test, (**C**). Agility performance test. Mean value and standard deviation are presented; % denotes percentage difference with Post WU; * denotes significant difference with P (15 min) at level $p < 0.001$; ** denotes significant difference with Post WU at level $p < 0.01$; # denotes significant difference with P (15 min) at level $p < 0.05$; WU, warm-up; P (15 min), passive rest for 15 min; 3 min RW, 12 min passive rest and 3 min re-warm-up.

In the agility test, no differences were observed between the two conditions (F = 3.557, $p = 0.315$, $\eta^2 = 0.151$). The soccer players' performance on the Illinois test decreased similarly after both passive rest and RW. The change in performance in the agility test is shown in Figure 4.

In the 10 m acceleration test, a significant negative effect of passive rest was observed (F = 16.935, $p < 0.001$, $\eta^2 = 0.435$) with the reduction in performance reaching 5.8%. In the 30 m test, the performance of the two conditions (P (15 min) and 3 min RW) differed from the performance immediately after the warm-up (F = 30.807, $p < 0.001$, $\eta^2 = 0.583$). The performance changes in the 10 m and 30 m tests are presented in Figure 5. Confidence intervals for jumps, sprints, and the Illinois test are presented in Table 3.

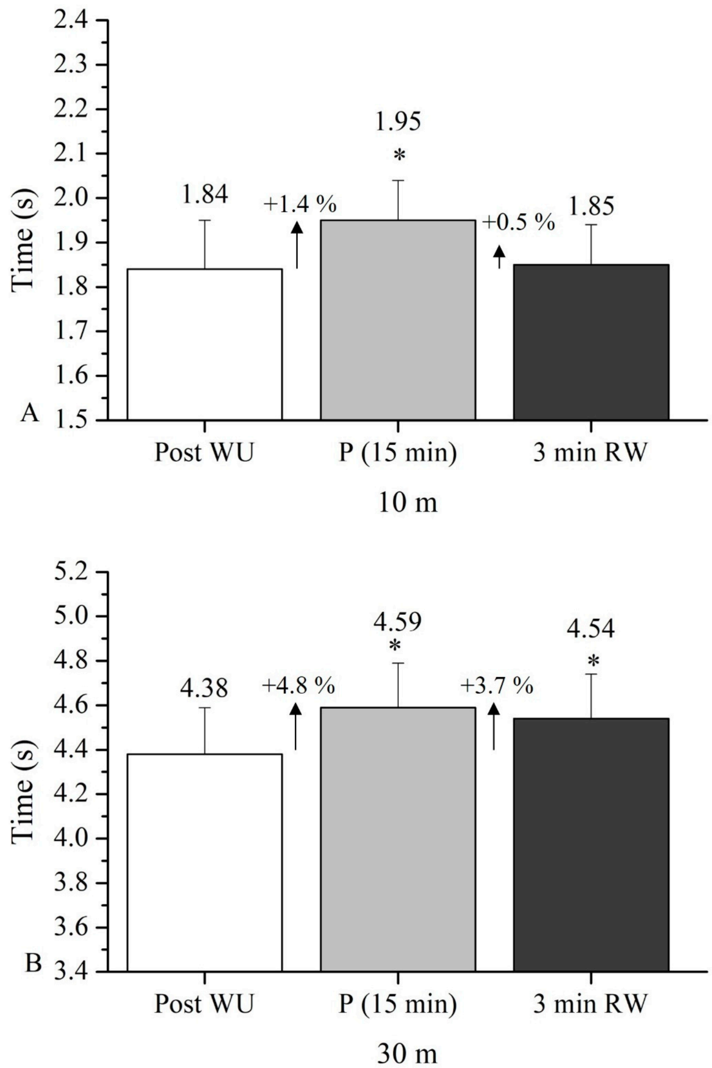

Figure 5. (**A**) 10 m performance test, (**B**) 30 m performance test. Mean value and standard deviation are presented; % denotes percentage difference with Post WU; * denotes significant difference at level $p < 0.001$ with post-WU; WU, warm-up; P (15 min), passive rest for 15 min; 3 min RW, 12 min passive rest and 3 min re-warm-up.

Table 3. Statistical results of physical performance measurements.

Test	Post WU		P (15 min)		3 min RW	
	Mean ± SD	**CI**	**Mean ± SD**	**CI**	**Mean ± SD**	**CI**
10 m (s)	1.84 ± 0.11	1.79–1.88	1.95 ± 0.09	1.91–1.99	1.85 ± 0.09	1.81–1.89
30 m (s)	4.38 ± 0.21	4.38–4.47	4.59 ± 0.20	4.50–4.67	4.54 ± 0.20	4.45–4.62
CMJ (cm)	38.5 ± 6.7	35.6–41.4	33.4 ± 6.3	30.6–36.1	35.7 ± 7	32.7–38.7
SJ (cm)	38.3 ± 5.4	35.9–40.6	34.9 ± 6.2	32.2–37.6	36.3 ± 7.2	33.2–39.5
Illinois test (s)	16.05 ± 0.48	15.83–16.27	16.27 ± 0.62	15.99–16.55	16.21 ± 0.39	16.03–16.38

CMJ, countermovement jump; SJ, squat jump; CI, confidence interval, WU, warm-up; P (15 min), passive rest for 15 min; 3 min RW, 12 min passive rest and 3 min re-warm-up.

Significant differences were observed in the heart rate (HR) of the soccer players between the two conditions (P (15 min) and 3 min RW) in the first quarter of the two halves ($p < 0.001$). Furthermore, differences were observed between the two halves in each condition ($p < 0.01$). The mean of HR is presented in Figure 6.

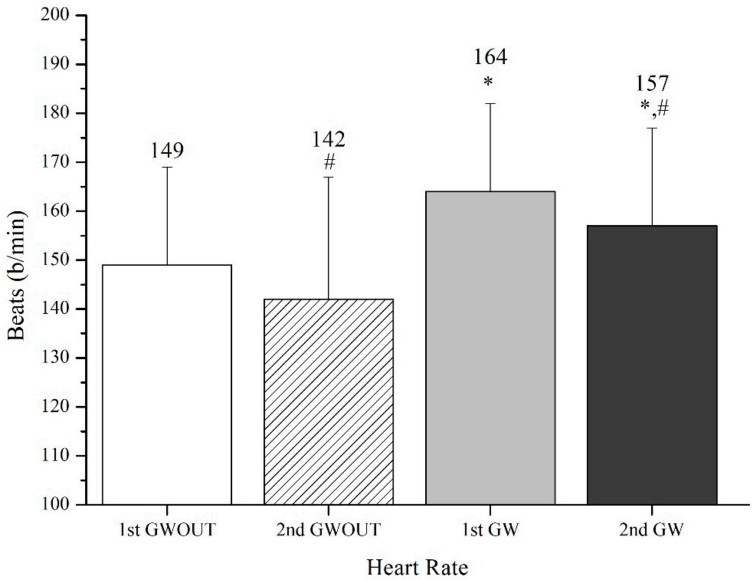

Figure 6. Average heart rate during the first quarter of each half. Mean value and standard deviation are presented; 1st GWOUT, 1st half of the matches with passive rest; 2nd GWOUT, 2nd half of the matches with passive rest; 1st GW, 1st half of the matches with 3 min re-warm-up; 2nd GW, 2nd half of the matches with 3 min re-warm-up; * denotes significant difference between conditions (match passive rest vs. match with 3 min re-warm-up) at level $p < 0.001$; # denotes significant difference between halves (of the same condition) at level $p < 0.01$.

Regarding the running performance of the soccer players, no difference was observed between the two conditions (P (15 min) and 3 min RW) in all variables (total distance, TD; average HR, HR; distance per minute, D/min; distance covered in four different velocity zones, z1: 7–10.99 km/h—z2: 11–14.99 km/h—z3: 15–18.99 km/h—z4: >19 km/h; number of accelerations, n; number of decelerations, n). These results are presented in Figure 7. The statistical indicators are presented in Table 4

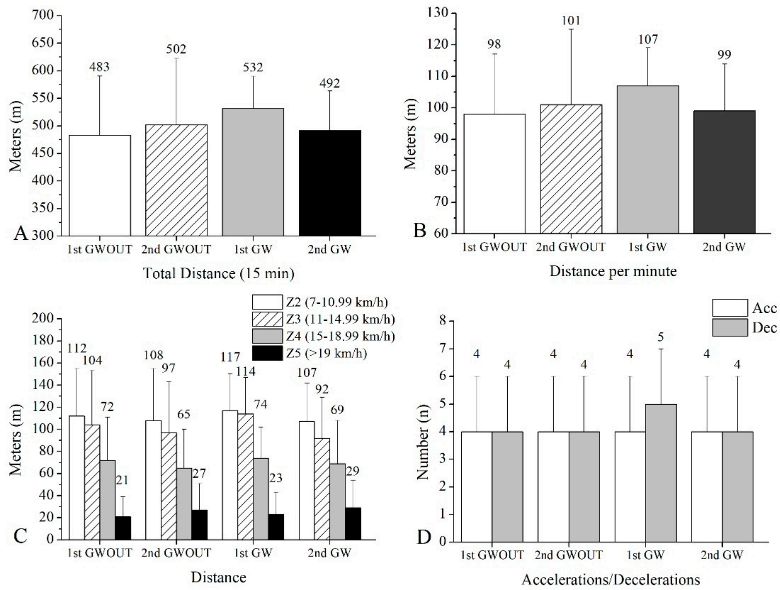

Figure 7. (**A**) Total distance (15 min), (**B**) distance per minute, (**C**) distance covered on specific velocity zones, (**D**) number of accelerations and Decelerations. Mean value and standard deviation are presented; 1st GWOUT, 1st half of the matches with passive rest; 2nd GWOUT, 2nd half of the matches with passive rest; 1st GW, 1st half of the matches with 3 min re-warm-up; 2nd GW, 2nd half of the matches with 3 min re-warm-up.

Table 4. Statistical results of heart rate and running performance measurements.

Test	Half	Trial	Interaction	CI: Half		.5 CI: Trial	
				1st	2nd	P (15 min)	3 min RW
HR (b/min)	F = 9.965 p = 0.003 η^2 = 0.156	F = 42.887 p < 0.001 η^2 = 0.443	F = 0.026 p = 0.872 η^2 <0.001	153–161	145–154	141–150	157–165
TD (m)	F = 0.721 p = 0.4 η^2 = 0.013	F = 2.596 p = 0.113 η^2 = 0.046	F = 4.594 p = 0.067 η^2 = 0.078	493–522	478–516	471–514	500–525
Tempo (d/min)	F = 1.416 p = 0.239 η^2 = 0.026	F = 1.872 p = 0.239 η^2 = 0.026	F = 3.832 p = 0.055 η^2 = 0.066	100–105	96–104	95–104	100–105
Z1 (m)	F = 2.013 p = 0.162 η^2 = 0.036	F = 0.218 p = 0.643 η^2 = 0.004	F = 0.367 p = 0.547 η^2 = 0.007	107–122	99–117	101–119	105–120
Z2 (m)	F = 6.413 p = 0.119 η^2 = 0.106	F = 0.186 p = 0.668 η^2 = 0.003	F = 1.595 p = 0.212 η^2 = 0.029	102–116	86–103	92–109	97–109
Z3 (m)	F = 1.563 p = 0.217 η^2 = 0.028	F = 0.371 p = 0.545 η^2 = 0.007	F = 0.024 p = 0.877 η^2 <0.001	67–79	60–75	62–76	64–79
Z4 (m)	F = 2.753 p = 0.103 η^2 = 0.049	F = 0.616 p = 0.436 η^2 = 0.011	F = 0.037 p = 0.848 η^2 = 0.001	18–27	22–33	20–29	22–31
Acc (n)	F = 0.383 p = 0.539 η^2 = 0.007	F = 1.142 p = 0.290 η^2 = 0.021	F = 3.313 p = 0.074 η^2 = 0.058	4.1–4.8	3.5–4.2	3.7–4.4	3.8–4.7
Dec (n)	F = 0.225 p = 0.125 η^2 = 0.118	F = 0.293 p = 0.591 η^2 = 0.005	F = 2.340 p = 0.132 η^2 = 0.042	3.8–4.5	3.5–4.4	3.8–4.6	3.6–4.3

HR, heart rate; TD, total distance; CI, confidence interval, P (15 min), passive rest for 15 min; 3 min RW, 12 min passive rest and 3 min re-warm-up.

4. Discussion

The aim of the present study was to investigate the effect of a short RW program on the performance of young soccer players in fitness tests and on their running performance during the first 15 min of the second half of league matches. The results of the present study seemed to confirm our hypothesis for some of the physical fitness tests but not for running performance in matches. More specifically, the short RW program of three minutes that we applied limited the decrease in body temperature and the performance in the intense power movements such as jumping and sprinting. However, the running performance of young soccer players did not appear to be affected by RW.

It is known that one of the main objectives of the warm-up is to increase the body temperature as it is particularly important for the performance of an athlete. More specifically, it has been reported that an increase of 1 °C in muscles can lead to a 2–5% improvement in muscle power [3]. Conversely, each decrease in temperature of 1 °C is accompanied by a decrease in performance of 3% [26]. In the present study, a significant decrease in body temperature was observed after passive rest (a 1.6% decrease). Body temperature after applying the RW program decreased by 0.8%. In a recent study [24], researchers observed that after 1 min of cycling to 90% or 3 min of cycling to 30% of VO_2max, performance in the sprint that followed increased. However, this study was carried out on active male adults. Similar positive effects were observed in a study of soccer players who applied 7 min of jogging at half-time [27].

In tests of acceleration (10 m) and speed (30 m), it was found that passive rest had a negative effect on the performance of young soccer players. More specifically, in the 30 m test, the athletes' time increased by 4.8%. Similar performance decline results have been reported in previous studies. In one of the first studies on this subject, a 2.6% yield decrease was observed [2], while in a more recent study, the decrement reached 3% [27]. These differences may be due to the different methodological approaches of the aforementioned studies such as the participants and the tests used. However, both of the above studies were carried out with the participation of adult soccer players who competed in the fourth division of the Danish league and the elite college league, respectively. It should be mentioned that in the present study, in the RW condition, a decrease in performance of 3.7% was observed. This drop is notable despite the fact that no statistical significance was observed. In addition to the partial eta square indicator, we see a large main effect of 15 min rest (η^2 = 0.583). Regarding the 10 m test, greater differences were observed between the two conditions. More specifically, after passive rest, the performance of soccer players decreased by 5.8%, while after RW, the decrement was only 0.5%. Additionally, regarding the partial eta square indicator, we see a large main effect between the conditions (η^2 = 0.435). Previous studies using the 10 m test reported a 2.6% decrement [16], while in studies that measured the speed at 10 m during a match, they observed a decrement of up to 6.2% [28]. Speed in soccer is a particularly important performance factor for the players. It has been reported in previous studies that most sprints during a soccer match last 2–4 s [29]. Therefore, if at the beginning of the second half, the soccer players show the differences observed in the present study for the 10 m sprint test (P (15 min): 1.95 s, decrement 5.8%; 3 min RW: 1.85 s, decrement 0.5%), this means that in a sprint of 2 to 4 s, the soccer player who would have applied RW would travel from 10.8 m to 21.62 m, while the one who would have applied passive rest would travel from 10.25 m to 20.5 m. As we understand, these differences from 0.55 m to 1.12 m can be very important to the outcome of the match. The different methodology can justify many of the differences that appear in the research results. However, they all conclude that using a RW schedule can limit the decline in speed test performance compared to passive rest.

In the jumps in the present study, a significant decline in performance was observed after passive rest. More specifically, in CMJ, the performance decreased by 13.2%, while in SJ, it decreased by 8.9%. It should be mentioned here that in the RW condition, decreases in both CMJ (7.3%) and SJ (5.2%) were also observed. In addition to the partial eta square indicator, we find a large main effect between the conditions for CMJ (η^2 = 0.575) and a large main effect on passive rest for SJ (η^2 = 0.539). In a previous study, Edholm et al. (2015) [16] reported a decline in CMJ performance smaller than that observed in the present study (7.6% for the control group and 3.1% for the RW group). A decrease in CMJ performance after passive rest is also reported by Lovell et al. (2013) [28], while Zois et al. (2013) [19] reported an increase in the flight-time-to-contraction -time ratio after RW. In a recent study, Fashioni et al. (2020) [30] observed better jumping performance after applying RW. However, the studies that have been applied to soccer players and have measured the change in jumping performance after RW are very limited. All of them report that RW reduced the performance decrement or improved it. Unfortunately, the different methodologies do not allow a comparison of the results. The decrease in body temperature is associated with a decrease in the performance of sprints and jumps [31]. Therefore, the drop in body temperature observed after both passive rest and RW may be the reason for the decrease in performance observed in the jumps. We can assume that the performance decreased less after RW program because the drop in body temperature was less.

In the Illinois agility test, the reduction in the soccer players' performance was similar for both conditions (3 min RW: 1%; P (15 min): 1.4%) without being statistically significant. From the review of the literature, we find that there is only one other study that used an agility test (the Arrowhead agility test) in the evaluation of performance after RW [27]. In that study, as in the present one, the RW program they implemented did not limit the decline in performance. Unfortunately, there are no other studies that used the same agility test to be able to make comparisons and draw more secure conclusions because the RW program had no effect. It should be mentioned here that the Illinois test applied in the present study is 60 m, while the Arrowhead test is approximately 35 m. The distances are too different to make any comparisons.

One of the aims of the study was to investigate the effect of the same RW program in the first 15 min of the second half. For this purpose, a comparison was made between the internal and external load indicators in the first 15 min of each half. From the results, it appeared that the HR differed both between the conditions and between the halves. In the present study, the soccer players showed a higher HR both in the first 15 min of the first half and also in the second half. Studies that evaluated the change in HR in soccer matches after RW are very few. Edholm et al. (2014) [16] observed that in the second half, soccer players started with a higher HR and approached the half-time average faster than the control group. The researchers hypothesized that in the RW group, aerobic metabolism was activated more quickly, limiting the contribution of anaerobic metabolism to the onset of the second half. In a recent study, Bang et al. (2022) [27] observed in a match simulation exercise that, after RW, soccer players in the first seven minutes of the second half showed less HR than the control group. The researchers attributed this to the more efficient functioning of the circulatory system (transportation of gases, nutrients for energy production, ad removal of derivatives of biochemical reactions) as in the same task, the circulatory system of the control group worked harder (more heart beats) to produce the same work.

Regarding the running performance indicators of the soccer players in the present study, no significant difference was found between the two conditions or between the halves. In one of the studies that used soccer matches to evaluate the effect of an RW program on sprinting, Mohr et al. (2004) [2] found that after passive rest, sprint performance decreased, while after RW, performance was unchanged. In another study (Edholm et al., 2014) [16], the researchers observed that in both conditions, the total distance covered by the soccer players in the first quarter of the two halves decreased (RW: 9% and CON: 4%). They also reported that there were no differences in distances covered at high intensities both between conditions and between halves. The findings of the present study have several elements in common with those of Edholm et al. (2014) [16]. However, it should be mentioned that the limited number of matches we used for the study (two in each condition) and the other studies (one match/condition) do not allow us to draw safe conclusions. For example, Edholm et al. (2014) [16] stated that the reduced running performance may be due to the increased possession of the ball that the RW team had in this match. It is also known that running performance in a match can depend on the dynamic of the opposing team, possession of the ball [32,33], formation [34], and weather/terrain conditions [35]. Even when talking about running performance comparisons, we should talk about effective playing time. More specifically, in a previous study [36], it was reported that in the first quarter of the first half, the effective playing time was 40 s/min, while in the first quarter of the second half, the corresponding time was 36.5 s/min. From this, we can understand that in order to make any comparison, we should refer to the same effective match time of play or talk about relative values, e.g., distance/minute. Edholm et al. (2014) [16] refer to this issue as in their study they observed ~10% less effective playing time in the second half compared to the first. They then calculated the running distances of the second half proportionally and reported that the soccer players showed greater running performance in the second half. However, this calculation involves a high risk of error.

As mentioned above, the primary goal of the application of RW is to keep the body temperature high or limit its decrease as much as possible. It has been reported in previous studies that high body temperature can accelerate anaerobic energy production (e.g., phosphocreatine hydrolysis) [37] by activating glycolytic enzymes [38] to produce ATP and improve cross-bridge cycling [37]. Furthermore, increased body temperature can enhance the transmission of nerve impulses and the speed of muscle contraction [39,40]. Thus, the differences that appeared between the two conditions (P (15 min) and 3 min RW) in some of the performance tests may be due to the maintenance of a higher body temperature.

In conclusion, in the present study, it was observed that a short half-time RW program can limit the decrease in body temperature and the speed and jumping performance of young soccer players. However, no changes were observed in running performance during the matches as there are many factors that can affect this performance such as team tactics, the opposing team, etc.

Limitations

The study has some limitations. One of the limitations is that the body temperature of the soccer players was not measured during the running performance measurements in the matches. Another limitation is that the effect of circadian rhythm on body temperature was not tested. The participants were high-level youth soccer players, but generalizations of the results to other populations cannot be made. Furthermore, the number of matches was too low to draw safe conclusions. In addition, match-related variables were measured over a 15 min period, while shorter periods (e.g., 5 min) could be used to distinguish potential differences that may be eliminated in the 15 min period. Finally, the present study was a descriptive study, and it is not possible to explain the observed changes in performance in depth.

Therefore, according to the above limitations of the study, we suggest future researchers measure the body temperature at more time points and take into account its circadian rhythm. More studies are also needed at developmental ages and in large samples.

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