

Comparison of two types of warm-up upon repeated sprint performance in experienced soccer players.

Running head: warming up and repeated sprint performance in soccer

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ABSTRACT

The aim of the study was to compare the effects of a long warm-up and a short warm-up upon repeated sprint performance in soccer players. Ten male soccer players (age 21.9 ± 1.9 yr, body mass 77.7 ± 8.3 kg, body height 1.85 ± 0.03 m) conducted two types of warm-ups with one week in between: a long warm-up (20 minutes: LWup) and a short warm-up (10 minutes: SWup). Each warm-up was followed by a repeated sprint test consisting of 8 x 30 m sprints with a new start every 30th second. The best sprint time, total sprinting time and % decrease in time together with heart rate, lactate and rate of perceived exertion (RPE) were measured. No significant differences in performance were found for the repeated sprint test parameters (total sprint time: 35.99 ± 1.32 s [LWup] and 36.12 ± 0.96 s [SWup]; best sprint time: 4.32 ± 0.13 s [LWup] and 4.30 ± 0.10 s [SWup] and % sprint decrease: 4.16 ± 2.15 % [LWup] and 5.02 ± 2.07 % [SWup]). No differences in lactate concentration after the warm-up and after the repeated sprint test were found. However, RPE and heart rate were significantly higher after the long warm-up and the repeated sprint test compared with the short warm-up. It was concluded that a short warm-up is as effective as a long warm-up for repeated sprints in soccer. Therefore, in regular training less warm-up time is needed; the extra time could be used for important soccer skill training.

Keywords: lactate, RPE, RSA

INTRODUCTION

In most sports, a warm-up is performed with an aim to prepare the body for high level performance and to prevent injuries when performing at that high level (16, 21). Many studies have investigated the effect of warm-up upon a subsequent sporting performance by manipulating the content, duration and intensity of warm-up combined with the recovery until the main activity (6, 16).

In soccer, players regularly need to produce maximal sprint efforts, also called repeated sprint ability (13). This ability is often trained for and tested with 6–18 sprints, varying between 20–40 m, with recoveries of between 15–30 seconds (19). To perform well on these sprints, which can make a difference in ball contests, it is important that the players have warmed-up, since including a warm-up has shown enhanced performance compared with no warm-up (23). Spencer et al. (27) suggested that there is an increasing aerobic contribution to repeated sprints and that it can be characterized as an intermediate performance (7). It is therefore important that the warm-up is of sufficient duration to elevate baseline VO_2 , while causing minimal fatigue (7). Earlier, it was found that a minimum of 10 minutes warm-up is needed to enhance performance, mainly as this increases muscle temperature (26). Bergh and Ekblom (3) found that increased muscle temperature had a positive effect upon maximal muscle strength, jump and sprint performances. They showed that average sprinting velocity increased by 4.7 % for every degree increase in muscle temperature.

It was also found that the intensity of warm-up had an effect upon repeated sprint performance (1, 28). Stewart and Sleivert (28) showed that warm-up at 60 % or 70 % of VO_2max had a positive effect upon time to exhaustion in repeated sprints, while a warm-up at

80% of $\text{VO}_2\text{-max}$ or no warm-up did not enhance performance. Bishop, Bonetti and Dawson

(4) also showed that a 15 minutes of continuous warm-up at anaerobic threshold resulted in poorer performance than warm-up at aerobic threshold. This impaired performance was associated with a greater metabolic acideamia and a reduction in the accumulated oxygen deficit (5). However, Anderson et al. (1) found that a warm-up with an intensity above the anaerobic threshold for 10 minutes resulted in faster times on repeated sprint performance than a warm-up with lower intensity. In addition, Bishop, Bonetti and Spencer (5) showed that an intermittent, high intensity warm-up had better results on intermediate performance than a warm-up at 65 % VO_2max . Zois et al. (30, 31) showed that high intensity warm-ups (small-sided games or 5-RM squatting) had a more positive effect on subsequent intermittent exercise compared with a team sport warm-up. However, most of these studies all began with a general warm-up (mostly jogging for five minutes or more) followed by a task-specific high intensity warm-up relevant to the ensuing exercise (5, 29–31). This warm-up sequence is motivated by injury prevention (15) and the premise that it takes time to get warm enough to perform at the highest level (6). It is possible that such a warm-up (general, low intensity part followed by high intensity exercises) is so long of duration that it causes increased pre-competition fatigue and prematurely elevates core temperature (30), which could impair repeated sprint performance. It is not clear if a short warm-up (consisting of only high intensity exercises) would get the same or better results.

Therefore, the aim of the present study was to compare the effects of a long (general and task-specific part) warm-up with a shorter (only task-specific, high intensity part) warm-up upon

repeated sprint performance in soccer players. It was hypothesized that the short warm-up would enhance repeated sprint performance more than the long warm-up, because of increased aerobic metabolism without significant inhibition of the anaerobic metabolism (5), while a long warm-up causes increased pre-competition fatigue and prematurely elevates core temperature (30), which could impair repeated sprint performance.

METHODS

Experimental approach to the problem

To compare the effects of the two warm-up protocols upon repeated sprint performance a repeated measurement design was conducted in which the subjects performed both warm-ups with one week in between. To avoid a learning effect from occasion to occasion a randomized cross over design was used, which implicated that half of the subjects started with the short warm-up, while the other half started with the long warm-up. The following week the order was swapped. The independent variables were the type of warm-up (a short or a long one) and the dependent variables were the repeated sprint performance, heart rates, lactate and rate of perceived exertion (RPE).

Subjects

Ten experienced soccer players playing in the third–fifth division of the national league (age 21.9 ± 1.9 yr, body mass 77.7 ± 8.3 kg, body height 1.85 ± 0.03 m) participated in the study. Before the start of the study, the subjects were fully informed about the protocol. Informed consent of all subjects was obtained prior to testing, with the approval of the local ethics committee and in accordance with the current ethical standards in sports and exercise research. The experiment was conducted at the start of the competition season, from March–April. The tests were always conducted on the same day and time of day, with the same

researchers at each performance test (19). Subjects were also instructed to avoid strenuous training 24 hours prior, alcohol consumption at least 12 hours prior, and food consumption two hours prior to each test.

Procedures

The subjects performed the two warm-up protocols followed by a repeated sprint test. The long warm-up started with the first five minutes of the Yo-Yo IR 1 test (2). Next, subjects walked for two minutes at 5.5 km/h on a treadmill, followed by five minutes running at 9 km/h. After this, dynamic flexibility exercises were performed (Figure 1) for four minutes, then running on a treadmill at 12 km/h for two minutes, followed by one minute of running at 15 km/h. Lastly, subjects performed four runs of 30 m at 80, 85, 90 and 95 % of self-estimated maximal 30 m speed. After three minutes of active recovery, the repeated sprint test was conducted. This long warm-up was based upon the training warm-up of an elite soccer team that has played in the Champions League and currently plays in the European League.

The short warm-up consisted of 8 x 50 m runs with a one minute rest in between. The first 50 m run was performed at a self-estimated intensity of 60 %. Each following 50 m run was performed with a 5 % increase in self-estimated intensity, reaching 95 % on the final run. In each rest period, one of the seven dynamic flexibility exercises for the shoulder, hip, knee and ankle joints was conducted, starting with the shoulders and working downwards (Figure 1). The aim of these exercises was to increase the range of motion of the different joints. The same exercises were used as in the long warm-up protocol. After the last 50 m run, three minutes of active recovery was taken before the start of the repeated sprint test.

The repeated sprint test consisted of 8 x 30 m sprints with a new start every 30th second. In the rest periods, the subjects jogged back to the start. The distance of 30 m was chosen because in a regular soccer match the average duration of movements with high intensity are between 3.7 and 4.4 seconds (27), which is similar to the duration of a 30 m sprint. All testing was conducted at an indoor sports hall on a pulastic surface (Pulastic 2000 TP, Sika Descol B.V., Deventer, the Netherlands).

Each 30 m sprint was measured with two pairs of wireless photocells using Brower equipment (Wireless Sprint System, USA). The subjects began with one foot before the other, 0.3 m behind the first pair of photocells, which were placed at a height of 0.3 m. The best and average sprint times were calculated, together with the total sprint time of all eight sprints and the fatigue index (20). This fatigue index was calculated by the formula, $\text{Fatigue} = (100 \times [\text{total sprint time} - \text{ideal sprint time}] - 100)$, in which the ideal sprint time was the best sprint time multiplied by the number of sprints.

Heart rate was measured every fifth second with a heart rate belt (Polar RS 400, Polar Electro, OY Kempele, Finland). Various heart rates were recorded: heart rate during the warm-up after each of the eight runs (short warm-up), heart rate straight after each part of the long warm-up (at seven points), average heart rate of the whole warm-up, heart rate straight after the warm-up and the heart rate after each sprint of the repeated sprint test. All these heart rates were given further analysis. Blood lactate concentration was taken from the index finger three minutes after completion of the repeated sprint test with the portable Lactate Pro LT-1710 (Arkray, KDK Corporation, Shiga, Japan). The received perception exertion (RPE) was measured on a Borg scale of 6–20, in which 6 indicated no exertion and 20 indicated maximal perceived exertion (8). The RPE was reported straight after each warm-up and the repeated

sprint test. The performance related physiological and perceptual variables (heart rate, blood lactate concentration and RPE) recorded before warm-up, after warm-up, after the repeated sprint test and three minutes after the repeated sprint test were used for further analysis.

Statistical analyses

The effects of the two warm-up protocols upon the repeated sprint performance variables (average sprint time, best sprint time, total sprint time and fatigue index) was tested by a one-way analysis of variance (ANOVA) with repeated measurements on each performance variable.

To test performance related physiological and perceptual variables (heart rate, blood lactate concentration and RPE) a 2 (warm-up protocol: long vs. short) x 4 (time: before warm-up, after warm-up, after repeated sprint test and three minutes after repeated sprint test) repeated ANOVA was used.

To assess the development of the sprint times and heart rate during the repeated sprint test for the two warm-up protocols, a 2 (warm-up protocol: long vs. short) x 8 (sprint attempt: 1–8) repeated ANOVA was used. When significant differences in sprinting times were found, a one-way ANOVA was conducted to locate eventual changes per protocol. Post hoc comparisons with Holm-Bonferroni corrections were conducted to locate differences. All results are presented as mean \pm SD. Where sphericity assumptions were violated, Greenhouse-Geisser adjustments of the p -values were reported. The criterion level for significance was set at $p < 0.05$. Effect size was evaluated with η^2 (ETA partial squared), where $0.01 < \eta^2 < 0.06$ constitutes a small effect, $0.06 < \eta^2 < 0.14$ constitutes a medium effect and

$\eta^2 > 0.14$ constitutes a large effect (12). Statistical analysis was performed in SPSS, version 21.0 (SPSS, Inc., Chicago, IL).

To test the reliability of the protocol, the eight sprint times after each warm-up protocol were used to calculate ICC by Crombachs' Alpha.

RESULTS

The reliability of the repeated sprint measurements was $ICC = 0.936$. The average, best and total sprint times and fatigue index after each warm-up protocol is shown in Table 1. No significant difference between the two warm-up protocols was found for either of the performance variables ($F \leq 2.15$; $p \geq 0.176$; $\eta^2 = 0.19$; Table 1). However, the performance related physiological and perceptual parameters showed different results. Although the average heart rate over the two protocols did not differ significantly (145 ± 9 [short warm-up]; 148 ± 13 [long warm-up]; $p = 0.29$), RPE ($F = 10.94$; $p = 0.016$; $\eta^2 = 0.646$) and heart rate ($F = 6.2$; $p = 0.027$; $\eta^2 = 0.51$) were significantly different between the two protocols (Figures 2 and 3) and the blood lactate concentration was not significantly different ($F = 4.76$; $p = 0.52$; $\eta^2 = 0.07$). Post hoc comparison showed that RPE was significantly higher for the long warm-up after the warm-up, the repeated sprint test and three minutes after that. The heart rate was only significantly higher straight after the long warm-up and after the following repeated sprint test (Figure 2).

When analysing the development of the heart rate and the sprint times during the repeated sprint test a significant increase in sprint times ($F = 9.54$; $p < 0.001$; $\eta^2 = 0.51$) was observed together with an increase in heart rate ($F = 257$; $p < 0.001$; $\eta^2 = 0.96$; Figure 4). No significant effect was found between the two protocols for the heart rate ($F = 4.14$; $p = 0.072$; $\eta^2 = 0.32$) and

sprint times ($F=.197$; $p=0.668$; $\eta^2=0.02$). However, an interaction effect was found for sprint times ($F=4.14$; $p=0.072$; $\eta^2=0.32$). One-way ANOVA showed that the sprint times in the short warm-up significantly increased ($F=1.97$; $p=0.175$; $\eta^2=0.17$), while no significant difference in sprint times was found for the long warm-up ($F=18.52$; $p<0.001$; $\eta^2=0.67$).

Post hoc comparison showed that the sprint times increased significantly for the short warm-up from sprint 1 to 2, from 2 to 4, from sprint 3 to 5 and between sprint 5 and 7 (Figure 4). The heart rate for both warm-up protocols showed almost the same development; it increased significantly until after sprint 5 (short warm-up) and before sprint 6 (long warm-up). Furthermore, the heart rate increased significantly more during the repeated sprint test for the long warm-up protocol compared with the short warm-up (interaction effect), as shown by the significantly higher heart rates (Figure 4) from before sprint 3 to after sprint 8 (except after sprint 5 and 7 and before sprint 8).

DISCUSSION

The purpose of the present study was to compare the effects of a long (a typical team-sport warm-up) and a short warm-up protocol upon repeated sprint performance in soccer players. The main findings were that no significant differences in the repeated sprint performance variables were found between the two warm-up protocols, except for the RPE and heart rate, which were higher after the long warm-up than the short warm-up. Furthermore, during the repeated sprint test the sprint times increased significantly with the short warm-up protocol, while no difference occurred with the long warm-up. In addition, during the repeated sprint test the heart rate increased more with the long warm-up than with the short warm-up.

The sprint results of this study are comparable with earlier studies on soccer players (9–11, 14, 22). In a study of elite male soccer players from Tunisia, Chaouachi et al. (11) found the same average sprint times (4.46s), but a higher fatigue index (5.87), however they only ran 7

x 30 m with a 25 second rest in between. On the other hand, Buchheit and Mendez-Villanueva (9) found a fatigue index of only 2.9 after a 10 x 30 m sprint test, but the subjects had a 30 second rest between each run that may be enough to show a lower fatigue index. However, they also ran slower (4.71s), which could be another reason for this low fatigue index. In a similar study, with 6 x 30 m sprints and a 30 second rest period, Muijka et al. (22) found a fatigue index of 4.6 and an average time of 4.39 seconds, which again is comparable with our results.

No significant differences were found in performance (average, best and total sprint times and fatigue index) of the repeated sprint test (Table 1) that could be explained by the duration of the warm-up. Bergh and Ekblom (3) showed that sprint performance increases when the muscle temperature increases. They also showed that the muscle temperature reaches a plateau 10 minutes after starting an exercise and that it does not increase after these 10 minutes (3, 7). The short warm-up was 10 minutes, which is also the time necessary to reach this plateau of increased muscle temperature. Consequently, a warm-up of longer than 10 minutes would not be beneficial for performance enhancement in terms of muscle temperature alone (7). The intensity of the short warm-up was probably high enough to reach this increased muscle temperature plateau. Unfortunately, it was not possible to measure this possible increased muscle temperature due to insufficient equipment.

Although no differences were found in overall repeated sprint performance after the two warm-up protocols, the analysis showed that individual sprint times increased after the short warm-up protocol, but did not change significantly after conducting the long warm-up (Figure 4). It seems that after the short warm-up protocol the subjects were fatigued earlier than in the long warm-up protocol. An explanation for this could be that, since the short warm-up only

consisted of eight sprints of 50 m, it was not sufficient to elevate baseline VO_2 , while causing minimal fatigue (7). At the end of the warm-up, the heart rate was higher after the long warm-up (180 vs. 163 beats min^{-1} ; Figure 2) than the short warm-up. These heart rates were around 90 % and 80 % of their maximal heart rate, which were probably around 80 % and 70 % of their maximal oxygen uptake (25). This increased heart rate could be due to improved perfusion of the working muscles (18), which could increase oxygen kinetics (14). These faster O_2 kinetics (18) increase the ability to resynthesize Phosphate Creatine (27), which appears to be one of the major factors for maintaining performance during repeated sprints (17, 19, 20).

Conversely, the opposite could be the case; the subjects may have been more fatigued from the long warm-up, as shown by the higher RPE straight after ending the warm-up. The duration of the long warm-up was twice as long as that of the short warm-up and associated with greater load units as shown by the higher heart rates during periods of the warm-up (Figure 3). This may be an indication of greater residual fatigue and inhibition of central and/or peripheral mechanisms responsible for muscle contraction, which could impair repeated sprint performance. (30). Thus, when they started the repeated sprint test they unconsciously paced themselves (Figure 4). Therefore, no significant decrease from sprint to sprint was found; this was not in line with earlier studies on repeated sprint tests (1, 11, 19). However, in other sports, Neiva et al (24) found that swimming performance in the first half of a 100m freestyle was better after a short warm-up compared to a long warm-up. In addition, they found that also the RPE was lower after a short warm-up compared with a standard warm-up, while swimming performance did not defer.

Some limitations of the present study were that the effect of these warm-ups upon repeated sprint performance was investigated but not the effect upon other motor abilities like maximal

sprint or jumping performances, which are important in soccer matches. In addition, more sprint repetitions should be involved to investigate if the difference in sprint time development after the two warm-up protocols continues or not, which would give more support to the two possible explanations. Furthermore, core temperature and oxygen uptake during the protocols should be measured to get a better understanding of what happens during the different warm-ups, and to examine if the possible explanations are correct. Thus, future studies should take note of these suggestions.

The main aim of the present study was to investigate whether a short, warm-up would get the same or better results in repeated sprint performance as a long warm-up (typical team sport). No significant differences in sprint performance was found, indicating that the short warm-up is good enough and therefore more time could be dedicated to important soccer training skills. Longitudinal studies, in which short warm-ups are consistently implemented, should be conducted to investigate the effect of this upon injury occurrence.

PRACTICAL APPLICATIONS

Our study showed that the short warm-up was as effective as the long warm-up upon the repeated sprint performance (average, best and total sprint time and fatigue index) of soccer players. These results have important implications for athletes, coaches and physical-training staff. It gives athletes and trainers the opportunity to engage in a shorter warm-up, without loss of repeated sprint performance. Implementing this in regular training would result in using less time to warm-up, thereby allowing more time for important soccer training skills.

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ACCEPTED

Table 1. Best, average and total sprint time together with the fatigue index (95% confidence limits), p-values and effect size (η^2) over the eight 30 m sprints with the short and long warm-up.

Parameter	Long warm-up	Short warm-up	p	η^2
Best sprint time (s)	4.32 (4.23-4.41)	4.30 (4.23-4.37)	0.52	0.05
Average sprint time (s)	4.50 (4.38-4.62)	4.51 (4.43-4.60)	0.64	0.03
Total sprint time (s)	35.99 (35.05-36.93)	36.12 (35.43-36.80)	0.67	0.02
Fatigue index	4.16 (2.62-5.70)	5.02 (3.54-6.50)	0.18	0.19

Figure Legends

Figure 1.

Different dynamic exercises to increase the range of motion during the warm-ups.

Figure 2.

Heart rate, lactate concentration and RPE (Mean \pm SD) before and after the warm-up, after the sprint test and three minutes after the sprint test for each warm-up protocol (short and long).

* indicates a significant difference ($p < 0.05$) between the two warm-up protocols.

Figure 3.

Average heart rate after each run in the short warm-up and straight after each part of the long warm-up absolute and relative in time.

Figure 4.

Heart rate before and after each sprint and sprint times of the repeated sprint test (Mean \pm SD) for each warm-up protocol (short and long).

* indicates a significant difference ($p < 0.05$) between the two warm-up protocols.

→ indicates a significant difference ($p < 0.05$) between this variable and all right from the arrow.

† indicates a significant difference ($p < 0.05$) between these two variables for the short warm-up.



Hip flexion / extension



Int. / external rotation



Ab / Adduction



Ankle rotation



Knee rotation



Hip rotation



Arm swing





