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The efficacy, and characteristics, of warm-up and re-warm-up practices in soccer players: a systematic review

Running head: Warm-up and re-warm-up in soccer players

Amri Hammami¹, James Zois², Maamer Slimani³, Mark Russell⁴, Ezdine Bouhlel¹.

¹Laboratory of physiology, faculty of medicine Ibnjazzar, Sousse, Tunisia. ²School of Sport and Exercise Science, Institute of Sport, Exercise and Active Learning (ISEAL), Victoria University, Melbourne, Australia. ³Faculty of Sciences of Bizerte, Bizerte, Tunisia. ⁴School of Social and Health Sciences, Leeds Trinity University, Leeds, UK.

Correspond author: Amri Hammami: Laboratory of physiology, faculty of medicine Ibnjazzar, Sousse, Tunisia.

Tel: +21624479504

E-mail: hammamiamri@hotmail.com

Address: Résidence Ferdaws lot 5, Mhamdia Benarous, 1145, Tunisia.
ABSTRACT

INTRODUCTION: This review aimed (i) to evaluate the current research that examines the efficacy of warm-up (WU) and re-warm-up (RWU) on physical performance, and (ii) to highlight the WU and RWU characteristics that optimise subsequent performance in soccer players. EVIDENCE ACQUISITION: A computerized search was performed in the PubMed, ScienceDirect and Google Scholar (from 1995 to December 2015) for English-language, peer-reviewed investigations using the terms "soccer" OR "football" AND "warm-up" OR "stretching" OR "post-activation potentiation" OR "pre-activity" OR "re-warm-up" AND "performance" OR "jump" OR "sprint" OR "running". EVIDENCE SYNTHESIS: Twenty seven articles were retrieved. Particularly, 22 articles examined the effects of WU on soccer performance and 5 articles focused on the effects of RWU. Clear evidence exists supporting the inclusion of dynamic stretching or postactivation potentiation-based exercises within a WU as acute performance enhancements were reported (pooled estimate changes of +3.46% and +4.21%, respectively). The FIFA 11+ WU also significantly increases strength, jump, speed and explosive performances (changes from 1 to 20%). At half-time, active RWU protocols including postactivation potentiation practices and multidirectional speed drills attenuate temperature and performance reductions induced by habitual practice. The data obtained in the present review showed that the level of play did not moderate the effectiveness of WU and RWU on soccer performance. CONCLUSION: This review demonstrated that a static stretching WU reduced acute subsequent performance, while WU activities that include dynamic stretching, postactivation potentiation exercises, and the FIFA 11+ can elicit positive effects in soccer players. The efficacy of an active RWU during half-time is also justified.

KEYWORDS: Pre-activity; stretching; post-activation potentiation; soccer
**Introduction**

Akin to the practices of nearly every athletic competition, a period of prior activity that seeks to enhance preparedness for subsequent exercise precedes soccer match-play. Typically, stretching, technical practice and activities of varying intensity commence within 60 min of kick-off and are usually complete within 10-15 min of a match starting. As the warm-up (WU) aims to transition the athlete from a state of rest to a state of exercise while minimising residual fatigue, it is not surprising that 79% of studies investigating the effects of WU practices on subsequent physical performance observed improvements.

Warm-up practices in soccer typically include methods such as static stretching (SS), dynamic stretching (DS), injury-preventive neuromuscular activities [e.g. FIFA 11+ program; 4], high-intensity short-duration WU and/or postactivation potentiation- (PAP) based exercises. These are in addition to technical or skill-based activities completed prior to competition. The duration of WU activities is governed by association and broadcasting regulation, but commonly last between 25 and 40 min. However, little is known of the optimal WU characteristics that facilitate enhanced performance in the professional soccer player.

From sports other than soccer such as distance running, it appears that an athlete’s normal WU practices may benefit from an increase in intensity. For example, increasing the intensity of the same distance (300 m) WU from 6 x 50 m of striding (separated by a 45-60 s active recovery) to include 200 m of race-pace running and 100 m of striding (2 x 50 m separated by a 45-60 s active recovery) improved subsequent 800 m time trial performance by ~1%. Such findings corroborate those observed in elite bob-skeleton athletes whereby an increased WU intensity (+30%) resulted in improved mean 20 m resisted sprint performance.
A substantial body of research has reported a decrement in the work-rate and physical performance of soccer players during the second half of competitive match-play \(^{11, 12}\). For example, during the initial stages of the second half, physical performance markers (total distance, high-speed running) of soccer players decreased when compared with the first 15 min of soccer match-play \(^{11}\). Additionally, risks of injuries increased significantly in the first 20 min of the second half \(^{13}\). The reduction in physical performance after half-time has been attributed to changes relating to muscle and core temperature (reduction by 1°C) caused by passive half-time practices \(^8\). Currently, little is known of the effects of active re-warm-up (RWU) during the half-time period of a soccer match. A recent narrative review \(^{14}\) reported that strategies like heat maintenance, RWU based on PAP, hormonal priming, and caffeine and/or carbohydrate consumption can provide positive results in terms of performance and physiological responses in team sports. Surprisingly, no detailed systematic review has been conducted on the effects of WU and RWU in soccer players which differentiates according to playing standard. Hence, this review aimed: (i) to evaluate the current research that examines the efficacy of WU and RWU on physical performance, and (ii) to highlight the WU and RWU characteristics that optimise subsequent performance in soccer players.
Methods

Search strategy

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement \(^{15}\) guided the conduct and reporting of this review. A systematic search of three electronic databases (PubMed, Google Scholar, and ScienceDirect) was conducted in December 2015 and included all papers until this time. The search period ranged from 1995 to 2015. The search terms "soccer" OR "football" AND "warm-up" OR "stretching" OR "post-activation potentiation" OR "pre-activity" OR "re-warm-up" AND "performance" OR "jump" OR "sprint" OR "running" were combined in a systematic sequence.

****Figure 1 near here****

Inclusion and exclusion criteria

Articles were sequentially excluded from the review based on specific criteria, being: A) articles examining the long-term training effects of WU, B) studies in which stretching or PAP were not employed within WU scheme (e.g., in isolation), (C) articles that did not report specific fitness outcomes related to soccer players or used only flexibility or kinematic variables, and (D) studies that were review papers. The review included original research articles assessing the acute effects of different WU modalities (SS, DS, neuromuscular preventive program, and high intensity or resistance-based WU) on physical performance (strength, power, and speed-dependent tasks) in soccer players.

Static stretching defined as the movement of a limb to the end of its range of motion and holding the stretched position for a defined duration \(^{16}\). Dynamic stretching was defined by \(^{12}\), involving controlled movement through the active range of motion for a particular joint. Post-activation potentiation refers to the acute improvement in muscular performance after bouts of
high-intensity exercises. Research also examining the effects of RWU on physical performance were included. Research involving randomized controlled trials or studies with repeated measures designs published in English language peer-reviewed journals, using instruments with high reliability and validity were eligible for inclusion. Only peer-reviewed articles were considered. Conference proceedings were excluded. Studies recruiting competitive soccer players from all age groups or genders were included.

**Quality analysis**

Relevant studies were identified through an initial screening of article titles and abstracts, followed by a full-text review of all articles deemed potentially relevant, and a final analysis of adherence to inclusion criteria. The Physiotherapy Evidence Database (PEDro) rating scale was chosen for quality assessment of the included studies. This rates validity on a scale of 1-11 according to the following criteria: 1) Eligibility criteria specified, 2) random allocation of subjects, 3) concealed allocation of subjects, 4) groups similar at baseline, 5) subject blinding, 6) therapist blinding, 7) assessor blinding, 8) less than 15% dropouts, 9) intention-to-treat analysis, 10) between-group statistical comparisons, 11) point measures and variability of the data. Item 1 is not used in the scoring because it is related to external validity.

**Statistical Analyses**

The relative change in performance outcomes if mean and standard deviations were available was calculated by equation 1.

**Equation 1:**  \( \frac{(\text{Mean}_{\text{post}} - \text{Mean}_{\text{pre}})}{\text{Mean}_{\text{pre}}} \times 100 \)
Where Mean\textsubscript{pre} represents the baseline value, Mean\textsubscript{post} is the post-intervention value.

Effect sizes (ES) were calculated according to Cohen (1988) and represent the difference between experimental and control condition means divided by the baseline standard deviation. This method permits the determination of the magnitude of the differences or the changes between the groups or experimental conditions for each study that provided absolute mean data and standard deviations. Magnitudes of change were classified as follow: ES < 0.2 was defined as trivial; 0.2–0.6 was defined as small; 0.6–1.2 was defined as moderate; 1.2–2.0 was defined as large; >2.0 was defined as very large; and >4.0 was defined as extremely large.
RESULTS

Study characteristics

In total, 259 articles were retrieved from the search strategy. Titles and abstracts were reviewed and full text sources screened according to the predefined exclusion criteria. Twenty-seven records were retained for the final analysis. The acute effects of a WU on soccer performance variables were examined by 22 articles whereas the remaining 5 articles focused on the effects of RWU. Of the 22 studies examining WU interventions, 13 articles implemented stretching protocols (either SS or DS), 7 articles reported postactivation potentiation (PAP) practices, and 2 articles implemented the FIFA 11+. Studies examining RWU activities included interventions based on passive heating, multidirectional speed drills, PAP practices, whole body vibration, and cycling. Most participants were highly trained, amateur, professional and/or elite, and were tested in temperate environments (reported temperature range 13–25 C). The present review also analyzed the effects of WU and RWU according to the level of play.

Effects of warm-up

The search identified 13 articles that implemented static or dynamic stretching protocols 2, 3, 18–28 (see table 1). The results analysis demonstrated that WU based on SS decreased acute physical performance in soccer players. The magnitude of performance decrement was small to moderate (pooled ES were 0.31 and 0.78 for jump and sprint performance respectively). However, DS increased physical performance with moderate to large effect (pooled ES were 0.41 and 1.13 for jump and sprint performance respectively). For WU based on PAP (Table 2), we identified 7 articles 5–7, 29–32. The results showed a small increase in jump performance (ES = 0.26) and a large improvement in sprint performance (ES = 0.79). The effects of the
FIFA 11+ were presented in 2 articles (Table 2). The results showed a moderate improvement (ES = 0.47 and 0.49 for jump and sprint performance respectively). The positive effects of WU containing DS, PAP and the FIFA and the negative effects of SS on soccer performance were consistent in amateur, professional and recreational players.

**Effect of re-warm-up**

The effect of different RWU strategies on physical and physiological outcomes in soccer players was investigated in 5 studies (Table 3). Two studies used 90 min of football match-play, and 3 studies used different intermittent specific activity. Given the differences in half-time strategies employed and performance indices investigated, we did not calculate pooled ES or mean changes; however, the results of each study are presented in table 2. Almost all studies reported that active RWU reduced the negative impact induced by passive half-time practices both on physiological (heart rate; HR, core temperature) or performance outcomes (jump, sprint, distance covered). With the few studies conducted about the effects of RWU, the results showed that the level of play did not moderate the effectiveness of active RWU on soccer performance.

**Methodological quality of studies**

The quality of the studies included in our analysis is presented in Table 4. The mean PEDro score was 5.7/10 (range 4 to 7). Almost of investigations were randomized and used crossover design with an acceptable sample size. For practical reasons, most studies did not adopt a blinding design, but all made a between-group comparison.
Discussion

Effects of WU based on static stretching

The present review reported that WU containing bouts of SS significantly reduces physical performance in soccer players compared to either without stretching or other types of WU. It has been reported that muscle strength \(^{26, 27}\) and vertical jump performance \(^{18}\) reduce after a WU containing SS. Moreover, WU that contained SS reduced specific performances such as slalom dribbling and speed during penalty kick \(^{38}\). The magnitude of performance decrement was small to moderate (pooled ES were 0.31 and 0.78 for jump and sprint performance respectively). Furthermore, WU containing SS negatively impacted physiological outcomes (e.g., HR, core temperature). Fletcher and Monte-Colombo \(^{18}\) showed that HR and core temperature were significantly higher following WU without SS (jogging or DS) compared with WU with SS. The authors concluded that the relative SS-induced impairments are generally attributed to the significant lower heart rate values and core temperature after SS compared with other WU modes. Recent reviews regarding the effect of SS on performance in the general population demonstrated that the detrimental effects of SS are mainly limited to longer durations (≥60 s) and that the usage of SS as the sole activity during WU routine should be avoided \(^{39, 40}\). For soccer players, the research identified 4 studies which implemented SS duration equal to, or less than 40s \(^{2, 3, 21, 28}\). However, a lower performance (strength, jump, sprint) compared with DS or no WU were still observed.

Effects of WU based on dynamic stretching

Concerning WU containing DS, results showed an important increase in performance with moderate to large effect (pooled ES were 0.41 and 1.13 for jump and sprint performance, respectively). For example, it has been demonstrated that WU containing DS caused an
increase of 6.2% in knee extension peak torque and an improvement of 3.9% in vertical jump height. The authors also reported that HR and core temperature were higher after DS than after SS. These increases in HR and core temperature could result in an increase in the blood flow, increase sensitivity of nerve receptors, and may explain partly the improvement in muscle performance enhancement. Moreover, it has been reported that professional soccer players increased sprint (2.1%) and agility performance (1.1%) after WU based on DS, compared with general WU without stretching. Warm-ups which include DS as opposed to SS or no stretching are most effective in the improvement of strength and high-speed performances in soccer.

Effects of WU based on PAP

Although several studies have attempted to identify the optimal procedure to elicit PAP before sporting activities, little is known about the optimal prescription when utilised by soccer players. The present review identified 6 articles that examined the effects of PAP on subsequent soccer tasks. Pooled estimate of change and ES indicated that WU based on PAP produced a small increase in jump performance (3.73%, ES = 0.26) and a large improvement in sprint performance (4.7%, ES = 0.79) compared with control or other WU activities. It has been demonstrated that WU using heavy resistance exercise (squat) can significantly increase repeated-sprint performance compared with WU based on DS. Furthermore, Zois et al. demonstrated that 5 RM leg press exercise (duration =15 s) led to a significant improvement in vertical jump and repeated sprint performance compared with a traditional soccer WU routine (duration = 23 min), or control condition. Similar findings were observed when subsequent intermittent exercise was performed. These results may encourage practitioners to include short periods of high-intensity WU tasks prior to subsequent intermittent team-
sport activity but consideration of the logistics of such actions should be noted. Alternative methods of inducing PAP that do not require such equipment or perceived risk to athlete may be considered.

It has been suggested that regulatory light chain phosphorylation was the primary mechanism of PAP and that muscle contractile response can be decreased by fatigue or alternatively enhanced via PAP. To date, many factors related to PAP such as preload modality, intensity, volume and recovery time were studied in general population. In soccer players, investigated the optimal recovery needed for PAP in soccer players. The authors reported a heterogeneous response to individual optimal recovery following a 3 RM squat, concluding that athletes were not all responsive to a uniform recovery period. The variability in time of potentiation was found in other research articles investigating PAP in volleyball players. Thus, with the encouraging results for the use of PAP during WU by soccer players, practitioners should be aware of the variability in recovery time. It is therefore recommended that PAP should be personalized to the individual. A method of using an individual potentiating workload, intensity and recovery duration will provide the optimal benefits for each player.

**Effects of the FIFA 11+**

Recently, it has been demonstrated that the FIFA 11+ which combines cardiovascular activation and preventive neuromuscular exercises was an effective method for reducing and preventing injury incidences in soccer players. Currently, only 2 studies have examined the acute effects of the FIFA 11+ WU on muscular performance. Bizzini et al. found significant improvements in jump (5.5%), sprint (2.2%) and balance (2.9%) performances accompanied with a positive impact on physiological outcomes after the implementation of
the FIFA 11+. Furthermore, demonstrated an acute improvement in reactive strength index after the combined FIFA11+ and whole body vibration compared with FIFA 11+ alone, or combined with isometric exercises in collegiate amateur soccer players. Given the few studies reporting on the acute effects of the FIFA 11+ as a WU tool, Future research should compare the effectiveness of the FIFA11+ with SS and DS-based WU on soccer players’ performance.

Effects of WU duration

The mean duration of WU investigated were 10 min, 6 min, and 25 min for WU based on SS and/or DS, PAP-based WU, and FIFA11+ WU respectively. Total WU duration represents an important factor for coaches and practitioners to consider. A shorter WU would provide more time for tactical and technical preparation especially before competitions. It may also permit athletes to avoid excessive increases in temperature and thermoregulatory strain. Time efficient PAP-based WU practices could provide soccer players with the optimal link between performance enhancement and time efficiency. Furthermore, a combination between DS and PAP may represent a good method for performance improvement in soccer, and this topic should be further explored.

Effects of RWU

Studies demonstrated that active RWU using agility drills (repeated 20 m soccer-specific runs at 70% HRmax) or vibration techniques (3 sets of 60 s of whole body vibration in squat position) can significantly attenuated the decrease in strength and jump performance observed in control trials at the start of second half. Furthermore, reported that an active RWU including cycling elevated core temperature during half-time and attenuated the decrease in
physical performance (distance covered) observed thereafter. Likewise, Edholm et al.\(^ {34}\) reported that traditional passive half-time rest leads to impaired sprint and jump performance (decrease by 2%, 6.7%) during the initial phase of the second half in professional soccer players whereas a RWU using low-/moderate intensity jogging and light calisthenics effectively attenuates such deteriorations. Additionally, a RWU based on a small-sided game significantly improved subsequent skilled performance (the Loughborough Soccer Passing Test) immediately post intervention and following a second period of intermittent activity\(^ {37}\). The authors purported this improvement to the “transfer appropriate processing” phenomenon in which the acquisition of specific motor skills can facilitate the transfer of cognitive processing in subsequent like-tasks.

**Effects of WU and RWU according to soccer players’ level**

Given that WU and RWU effects on soccer players’ performances can be affected by the level of play and/or playing experience due to motivation, we analysed in the present review an overview of the results of the different WU and RWU used according to the level of the players (table 5 and table 6). Concerning the effects of WU, it seems that the relative static stretch-induced impairments and dynamic stretch-induced enhancements are similar in elite, professional and collegiate soccer players\(^ {18,21,28}\). The same conclusion for PAP-based WU can be drawn. The results indicated that the benefits from WU based on PAP especially upon explosive performance were consistent with the different level of play\(^ {6,29,30}\). These results seem to be similar to the results found when PAP applied in general population\(^ {39}\). Concerning the effects of RWU, the results according to the level of play were presented in Table 6. Within the few studies conducted, the positive effects of active RWU (aerobic exercises, agility drills and PAP) compared with passive RWU were consistent either in elite,
professional and amateur soccer players\textsuperscript{36,37}. Although comparison between different studies may present some methodological limits, future studies should investigate the effects of different WU and RWU methods upon physical performance in soccer players with different level or play experience.

In summary, an active RWU significantly attenuates the temperature and performance decrement during the half-time and the second half period in soccer players. This has important implications for athletes and soccer practitioners looking to enhance physical performance during the second half of competitive soccer. Although often considered crucial for tactical reasons, half-time periods can be physiologically considered as a recovery and a preparatory period preceding subsequent competition. Moreover, practitioners should employ active RWU according to the time between stimulus and the start of second match-play.

**Conclusion**

The present review shows that WU containing static stretching, dynamic stretching, PAP and the FIFA 11+ have different implications and adaptations on acute physical performance. It appears that WU based on SS reduces significantly soccer players' physical performance such as sprinting, jumping and strength indices. However, WU based either on DS, PAP and the use of the FIFA 11+ provides acute improvement or, at least does not negatively affect soccer-specific performance. Due to the few studies and lack of consistency especially on the effects of the FIFA 11+, further investigations are required to compare WU during practical situations and their effects on soccer-specific physical performances.
**Implications for practice**

Existing literature showed that conducting a WU with static stretching reduced acute subsequent performance, while WU activities that include dynamic stretching, PAP-based exercises, and the FIFA 11+ can elicit positive effects in soccer players. The efficacy of an active RWU during half-time is also justified. Based on the evidence of this review, a successful WU regimen for soccer players should contain either dynamic stretching exercise or PAP. These two modes of WU were effective in enhancing acute physical performance. Furthermore, the use of the FIFA 11+ can result in important gains especially in strength performance in addition to its previously demonstrated potential benefits for injuries preventions. However, Due to the nature of soccer play (90 minutes of activities including short sprints, jumps and other explosive actions), any “negative or positive effect” of a WU regimen would “disappear” after a few intense actions. For these reasons, the effects of different WU types on soccer players’ performance using more realistic situations (real or simulated soccer matches) are needed in order strength the evidence of the conclusion. Moreover, as noted previously, further research is necessary to validate the efficacy of the FIFA 11+ WU in comparison with other practical WU. Task-specific WU such as small-sided games seem to be an efficient WU method especially for enhancing task specific activity. Further research is required to confirm the benefits of small-sided games prior to soccer competition.

From the sparse RWU studies which currently exists it seems that traditional passive half-time period during soccer match causes temporary impairment in the players’ physical performance capacity. Soccer-specific activity completed at high-intensity with short-durations may provide an ergogenic aid for subsequent physical performance. This is especially relevant if the protocol avoids inducing additional levels of fatigue prior to commencement of competition. Although an active RWU including agility drills (soccer-
specific runs at high-intensity), whole body vibration techniques, cycling, and PAP exercises were effective methods for attenuating the negative effects of passive half-time strategies, it is necessary to consider the time demands and situational factors during the half time periods. In this context, further research should examine the optimal procedure of RWU within a short time-frame during the half time period.

Disclosure statement

No potential conflict of interest was reported by any one of the authors

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45. Tomaras EK, MacIntosh BR. Less is more: standard warm-up causes fatigue and less warm-up permits greater cycling power output. J Appl Physiol 2011;111:228-235.
Tables and Figures

Figure 1 Flow diagram of literature screening process.
Table 1. Summary of studies examining the effects of WU based on static and/or dynamic stretching on soccer players’ performances.

<table>
<thead>
<tr>
<th>References</th>
<th>N; gender</th>
<th>Age (years)</th>
<th>level</th>
<th>Warm-up modality</th>
<th>Warm-up duration; repetition</th>
<th>Rest period</th>
<th>Performances measures: Percentage of changes (effect size) #</th>
</tr>
</thead>
</table>
| Aguilar et al. (2012) | 23M/22F | 22.3 | Recreational | A) Cycling  
B) Cycling + SS  
C) Cycling + dynamic WUs | A) 5 min  
B) 15min  
C) 15 min | NR | Concentric peak torque  
Eccentric peak torque  
ROM  
CMJ  
DJ  
Peak Torque |
| Fletcher and Monte- | 21/M | 20.8 ± 2.3 | Semi-professional | A) Jogging  
B) Jogging + SS | A) 5 min  
B) 5 min + 360s | 1 min | Concentric peak torque  
Eccentric peak torque  
ROM  
CMJ  
DJ  
Peak Torque |
<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Participants</th>
<th>Design</th>
<th>Protocol</th>
<th>Measures</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombo, (2010 a)</td>
<td>27/M</td>
<td>20.5 ± 2.2 Semi-professional</td>
<td>A) Jogging B) Jogging + SS C) Jogging + DS</td>
<td>C) 5 min + (12 times each exercise)</td>
<td>B &lt; A: ↓ 3.7% (0.37)* C &gt; A: ↑ 3.9% (0.39)* C &gt; B: ↑ 8% (0.79)*</td>
</tr>
<tr>
<td>Fletcher and Monte-Colombo, (2010 b)</td>
<td>26/M</td>
<td>23.3 ± 3.2 Professional</td>
<td>A) Jogging B) Jogging + SS C) Jogging + Dynamic exercises D) Jogging + SS+dynamic exercises</td>
<td>C &gt; A: ↑ 5%* C &gt; B: ↑ 6.7%*</td>
<td></td>
</tr>
<tr>
<td>Gelen (2010)</td>
<td>18/M</td>
<td>NR</td>
<td>A) Jogging + sprint + agility runs B) Warm-up A + SS C) Warm-up A + DS</td>
<td>C &gt; A: ↑ 2.1% (0.95)*</td>
<td></td>
</tr>
<tr>
<td>Little and Williams, (2006)</td>
<td>19/M</td>
<td>22.5 ± 2.5 Professional</td>
<td>A) Jogging B) Jogging + SS C) Jogging + DS D) Jogging + SS+DS</td>
<td>C &gt; A: ↑ 1.1% (0.36)</td>
<td></td>
</tr>
<tr>
<td>Amiri-Khorasani et al., (2010)</td>
<td>22/M/</td>
<td>17.2 ± 1.2 Elite</td>
<td>A) Jogging + SS B) Jogging + DS C) Jogging + DS + Squats</td>
<td>C &gt; A: ↑ 13.35% (1.10)</td>
<td></td>
</tr>
<tr>
<td>Needham et al., 22/M/ (2009)</td>
<td>29/M</td>
<td>College</td>
<td>A) Control B) Running C) Running + DS D) Running + DS + SS E) SS F) Running + SS G) Running + SS+ DS</td>
<td>C &gt; B: ↑ 16.2% (0.64)* C &gt; A: ↑ 6.2% (0.46)*</td>
<td></td>
</tr>
</tbody>
</table>
| Pagaduan et al., 2012 | 2012 | 19.4 ± 1.1 College | A) Rest B) 5 min C) 12 min D) 19 min E) 7 min F) 12 min G) 19min | C > A: ↑ 7.41% (0.58) D > A*: 10.97% (0.92) F > A*: 13.35% (1.10)
### Table 2: Summary of studies examining the effects of WU based on PAP and the FIFA 11+ on soccer players’ performance.

<table>
<thead>
<tr>
<th>References</th>
<th>N; gender</th>
<th>Age(years)</th>
<th>level</th>
<th>Warm-up modality</th>
<th>Warm-up duration; Rest period repetition</th>
<th>Performances measures</th>
<th>Percentage of changes (effect size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sander et al., (2013)</td>
<td>121/M</td>
<td>15.1</td>
<td>Elite</td>
<td>A) Running + coordination + DS + acceleration run B) Warm-up A + functional exercise of trunk muscles</td>
<td>A) 13 min B) 13 min + (3 sets of 4 functional exercises)</td>
<td>[10m sprint A &gt; B: ↑1.1% (0.30)* 30m sprint A &gt; B: ↑0.97% (0.15)* 10m COD left A &gt; B: ↑1.8% (0.22)* 10m COD right A &gt; B: ↑1.5% (0.22)*]</td>
<td></td>
</tr>
<tr>
<td>Sayers et al., (2008)</td>
<td>20/F</td>
<td>18-29</td>
<td>Elite</td>
<td>A) Running B) Running + SS</td>
<td>A) Running a 800m 10s-2min B) Running a 800m + (3 x 30s per muscle group)</td>
<td>[NR 30m Sprint B &gt; A*]</td>
<td></td>
</tr>
<tr>
<td>Taylor et al., (2013)</td>
<td>11/M</td>
<td>24±3</td>
<td>Sub-elite</td>
<td>A) Cardiovascular Phase + task-specific activity B) Warm-up A + SS C) Warm-up A + DS</td>
<td>A) 10.95 min B) 21.58 min C) 20.53 min</td>
<td>[RSA fast time B &lt; A: ↓1.1% (0.23) RSA mean time C &gt; A: ↑0.7% (0.15)]</td>
<td></td>
</tr>
<tr>
<td>Zakas et al., (2006 a)</td>
<td>16/M</td>
<td>13.0 ±0.5</td>
<td>Talented.</td>
<td>A) Cycling + SS (duration 1) B) Cycling + SS (duration 2)</td>
<td>A) 5 min + (3 x 15s) B) 5 min + (20 x 15s)</td>
<td>[Pre-to post-ROM A: ↑2.75 % (0.79)* B: ↑3.09% (0.87)* Concentric peak isokinetic torque 60°/s A: ↓0.2% (0.02) B: ↓5.46% (0.36)* 180°/s A: ↓1.08% (0.09) B: ↓8.41% (0.60)* Knee joint ROM Pre-and post A: ↑2.8% (0.77)* B: ↑2.9% (0.78)* Leg extensors Peak torque 60°/s A: ↓0.2% (0.02) B: ↓5.6% (0.39)* 270°/s A: ↓0.56% (0.04) B: ↓8.18% (0.65)*]</td>
<td></td>
</tr>
<tr>
<td>Zakas et al., (2006 b)</td>
<td>15/M</td>
<td>25.0 ± 1.5</td>
<td>Professionnel</td>
<td>A) Cycling + SS (duration 1) B) Cycling + SS (duration 2)</td>
<td>A) 5 min + (4 x 15s) B) 5 min + (32 x 15s)</td>
<td>[Knee joint ROM Pre-and post A: ↑2.8% (0.77)* B: ↑2.9% (0.78)* Leg extensors Peak torque 60°/s A: ↓0.2% (0.02) B: ↓5.6% (0.39)* 270°/s A: ↓0.56% (0.04) B: ↓8.18% (0.65)*]</td>
<td></td>
</tr>
</tbody>
</table>

↓: Significant change or difference; NR: not reported; M: male; F: female; SS: static stretching; DS: dynamic stretching; ROM: range of motion; COD: change of direction.

*: significant difference

#: Change and effects size calculated if sufficient data available
### I. Warm-ups based on PAP

<table>
<thead>
<tr>
<th>Study</th>
<th>Gender</th>
<th>Age ± SD</th>
<th>Type</th>
<th>Warm-up Intervention</th>
<th>Duration</th>
<th>Outcome Measures</th>
<th>Comparison</th>
</tr>
</thead>
</table>
| Low et al., (2015)       | 16/M   | 17.1 ± 0.65 | Athlete           | A) Jogging+ DS  
B) Jogging + DS + back squat (3 x 91% of maximal repetition)                   | 10 min   | Sprint 1 (RSA), sprint 2 (RSA), total sprints (RSA) | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Pojskic et al., (2015)   | 21/M   | 14 ± 1.65  | College            | A) Running  
B) Running + DS  
C) Running + static half squat  
D) Running + static half squat + 30% of body weight | 5 min    | CMJ after 2 min, 15m: after 1 min of CMJ  
T test: after 1 min of sprint | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Pojskic et al., (2015)   | 21/M   | 14 ± 1.65  | College            | A) Running  
B) Running + DS  
C) Running + static half squat  
D) Running + static half squat + 30% of body weight | 5 min    | CMJ after 2 min, 15m: after 1 min of CMJ  
T test: after 1 min of sprint | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Pojskic et al., (2015)   | 21/M   | 14 ± 1.65  | College            | A) Running  
B) Running + DS  
C) Running + static half squat  
D) Running + static half squat + 30% of body weight | 5 min    | CMJ after 2 min, 15m: after 1 min of CMJ  
T test: after 1 min of sprint | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Till and Cooke, (2009)   | 12/M   | 18.3 ± 0.72 | Professional academy | A) Jogging + dynamic exercises  
B) warm-up + deadlift exercise (5 RM)  
C) warm-up + plyometric exercise (tuck jump)  
D) warm-up + isometric MVCs | 5 min    | CMJ, Reactive agility, Mean 20m RSA  
CMJ: D > A (6%), C > A (2%)  
Reactive agility: D > A (8%), C > A (7%)  
Mean 20m RSA: B > A (6%) | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Pojskic et al., (2015)   | 10/M   | 23.3 ± 2.5 | Amateur            | A) Jogging  
B) Jogging + team-sport WU  
C) Jogging + 5 RM leg-press  
D) Jogging + small-sided game | 5 min    | CMJ, Reactive agility, Mean 20m RSA  
CMJ: D > A (6%), C > A (2%)  
Reactive agility: D > A (8%), C > A (7%)  
Mean 20m RSA: B > A (6%) | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Pojskic et al., (2015)   | 10/M   | 23.3 ± 2.5 | Amateur            | A) Jogging  
B) Jogging + team-sport WU  
C) Jogging + 5 RM leg-press  
D) Jogging + small-sided game | 5 min    | CMJ, Reactive agility, Mean 20m RSA  
CMJ: D > A (6%), C > A (2%)  
Reactive agility: D > A (8%), C > A (7%)  
Mean 20m RSA: B > A (6%) | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
| Pojskic et al., (2015)   | 10/M   | 23.3 ± 2.5 | Amateur            | A) Jogging  
B) Jogging + team-sport WU  
C) Jogging + 5 RM leg-press  
D) Jogging + small-sided game | 5 min    | CMJ, Reactive agility, Mean 20m RSA  
CMJ: D > A (6%), C > A (2%)  
Reactive agility: D > A (8%), C > A (7%)  
Mean 20m RSA: B > A (6%) | B > A: ↑0.39% (0.13), B > A: ↑1.63% (0.36)* |
B) Jogging + submaximal runs + half squat without WBV  
C) WUA + half squat + WBV  
D) WUA + half squat + WBV + (50hz)  
E) WUA + half squat + WBV + (30hz)  
F) WUA + half squat + WBV + (15hz) | 10 min   | CMJ, Peak power, Jump height  
CMJ: B = 4.0 ± 0.5%  
Peak power: C > A (4.2 ± 2.1%)  
Jump height: B > A (4.3 ± 2.0%) | B > A: ↑0.65% |
| Mola et al., (2014)      | 22/M   | 23 ± 4.5  | Professional      | A) Cycling + DS  
B) Cycling + DS + squat | 7min     | CMJ, Peak power, Jump height  
CMJ: B = 4.0 ± 0.5%  
Peak power: C > A (4.2 ± 2.1%)  
Jump height: B > A (4.3 ± 2.0%) | B = A: |

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**Notes:**
- RSA: Reactive agility speed test.
- CMJ: Countermovement jump.
- WBV: Whole-body vibration.
- WUA: Warm-up activity.
- 1RM: One-repetition maximum.
- 15m: 15-meter sprint.
- 40m: 40-meter sprint.
### II. The FIFA 11+ warm-up

<table>
<thead>
<tr>
<th>Authors</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Level</th>
<th>Protocols</th>
<th>Re-warm-up intervention</th>
<th>Performances measures: Percentage of changes</th>
<th>balance: SEBT:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bizzini et al., 2013</td>
<td>20/M</td>
<td>25.5 ± 5.1</td>
<td>Amateur</td>
<td>FIFA 11+</td>
<td>20-25 min</td>
<td>20m           SFJ       Agility</td>
<td>↑2.2% (0.47)</td>
</tr>
<tr>
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</tr>
<tr>
<td>Cloak et al., 2014</td>
<td>74/M</td>
<td>20.0 ±1.2</td>
<td>Collegiate amateur</td>
<td>A) FIFA 11+</td>
<td>20-25min</td>
<td>15s post WU    505 agility: 4 min post WU</td>
<td>Pre-and post test: RSI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B) warm-up A+30s</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C) FIFA 11+ + isometric squat</td>
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</tbody>
</table>

↓↓: Significant performance increase or decrease compared with pre-test, control condition, or between groups; NR: not reported; M: male; F: female; WBV: whole body vibration; RSI: Reactive strength index; *: significant difference #: Change and effects size calculated if sufficient data available

---

**Table 3** Summary of studies examining the effects of re-warm-up strategies on performance in soccer players

<table>
<thead>
<tr>
<th>References</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Level</th>
<th>Protocols</th>
<th>Re-warm-up intervention</th>
<th>Performances measures during half-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edholm et</td>
<td>22/M</td>
<td>90 min match</td>
<td>Professional</td>
<td>A) Control (seated rest)</td>
<td>Tests: pre (after warm-up), After half 1, After intervention (before half 2).</td>
<td></td>
</tr>
</tbody>
</table>
B: 7 min rest + 7 min jogging + calisthenics

10 m sprint
Pre: A=B
After half 1: A=B
After intervention: A>B:
No Change

Heart rate
After intervention: B>A*

Defensive high-intensity running
A>B

Tests: pre, and half 1 at first 15min, 2nd 15min, 3rd 15min, after intervention.

Sprint
Half 1, 3rd 15min vs. first 15min
A: ↓ 2.4±2.6%
B: ↓ 1.4±2.6%
C: ↓ 2.2±1.5%

Half 2, 3rd 15min vs. first 15min
A: ↓ 7.2±4.8%
B: ↓ 5.8±4.0%
C: ↓ 4.5±2.6%

CMJ
During half time (after intervention)
C > A*  B=C

Peak torque: Concentric hamstring
The decrease was less for B vs A*

Eccentric Hamstring
The decrement in Eccentric Hamstring across the HT interval was significant in A, but not in B and C.
Table 4. Methodological qualities of the included studies

<table>
<thead>
<tr>
<th>References</th>
<th>Study</th>
<th>Item number</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aguilar et al. (2012)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Bizzini et al., (2013)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Cloak et al., (2014)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Edholm et al., (2014)</td>
<td>RWU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Fletcher and Monte-Colombo,( 2010 a)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Fletcher and Monte-Colombo,( 2010 b)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Gelen, (2010)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Little and Williams, (2006)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Lovell et al., (2007)</td>
<td>RWU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Lovell et al., (2013)</td>
<td>RWU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Low et al., (2015)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Amiri-Khorasani et al., (2010)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Mohr et al., (2004)</td>
<td>RWU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Mola et al., (2014)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Needham et al., (2009)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Pagaduan et al., (2012)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Pojskic et al., (2015)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Rønnestad and Ellefsen, (2011)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>7</td>
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<tr>
<td>Sayers et al., (2008)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
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<tr>
<td>Sander et al., (2013)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>5</td>
</tr>
<tr>
<td>Taylor et al., (2013)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Till and Cooke, (2009)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Zakas et al., (2006a)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Zakas et al., (2006b)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Zois et al., (2011)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Zois et al., (2015)</td>
<td>WU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
<tr>
<td>Zois et al., (2013)</td>
<td>RWU</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
<td>6</td>
</tr>
</tbody>
</table>

*: Not included in scoring
# Table 5 The effects of WU on performance of soccer players according to level of play

<table>
<thead>
<tr>
<th>Level of players</th>
<th>Type of WU</th>
<th>Number of studies</th>
<th>Overview of the results*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amateur</strong></td>
<td>WU based on SS or/and DS</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>WU based on PAP</td>
<td>2</td>
<td>↑20 and 40m sprint, ↑CMJ, ↑Reactive agility</td>
</tr>
<tr>
<td></td>
<td>WU based on FIFA</td>
<td>2</td>
<td>↑ SJ, ↑ Agility, ↑ Balance, ↑Reactive strength index</td>
</tr>
<tr>
<td><strong>Professional</strong></td>
<td>WU based on SS or DS</td>
<td>7</td>
<td>SS: ↑Agility, ↓Slalom dribbling, ↓Penalty kick, ↓Concentric isokinetic peak torque, ↑ROM</td>
</tr>
<tr>
<td></td>
<td>WU based on PAP</td>
<td>3</td>
<td>↑CMJ, ↑Reactive agility, ↑RSA</td>
</tr>
<tr>
<td></td>
<td>WU based on FIFA</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td><strong>Elite</strong></td>
<td>WU based on SS or/and DS</td>
<td>3</td>
<td>SS: ↓RSA, ↑30m sprint</td>
</tr>
<tr>
<td></td>
<td>WU based on PAP</td>
<td>1</td>
<td>↑CMJ, ↑10 and 20m</td>
</tr>
<tr>
<td></td>
<td>WU based on FIFA</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td><strong>Collegiate/Recreational</strong></td>
<td>WU based on SS or/and DS</td>
<td>4</td>
<td>SS only: ↓CMJ, ↓Concentric isokinetic peak torque</td>
</tr>
<tr>
<td></td>
<td>WU based on PAP</td>
<td>1</td>
<td>Compared with general WU: ↑Agility ↑15m sprint</td>
</tr>
<tr>
<td></td>
<td>WU based on FIFA</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

**Abbreviations:** WU: warm-up, SS: static stretching, DS: dynamic stretching, FIFA: the FIFA 11+ warm-up, SJ: squat jump, CMJ: countermovement jump, ROM: range of motion

*: Performances changes after the different conditions were compared either with baseline values or with control condition (rest, general warm-up)
Table 6 The effects of RWU practices on performance of soccer players according to level of play

<table>
<thead>
<tr>
<th>Level of players</th>
<th>Type of RWU</th>
<th>Number of studies</th>
<th>Overview of the results*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amateur</td>
<td>Rest/ Passive heating</td>
<td>1</td>
<td>No changes in performances</td>
</tr>
<tr>
<td></td>
<td>Aerobic exercises</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Specific drills, PAP</td>
<td>1</td>
<td><strong>PAP</strong>: ↑RSA, ↑CMJ CMJ and soccer passing test performances were superior after PAP and Small-sided game RWU compared with rest.</td>
</tr>
<tr>
<td>Professional</td>
<td>Rest/ Passive heating</td>
<td>2</td>
<td>↓10m sprint and CMJ after rest condition</td>
</tr>
<tr>
<td></td>
<td>Aerobic exercises</td>
<td>1</td>
<td>No change in 10m sprint after jogging</td>
</tr>
<tr>
<td></td>
<td>Specific drills, PAP</td>
<td>1</td>
<td>Decreases in sprint performance were greater after rest versus agility or vibration exercises.</td>
</tr>
<tr>
<td>Elite</td>
<td>Rest/ Passive heating</td>
<td>1</td>
<td>During second half: ↓ 3.1% Distance covered after rest condition greater than after other passive heating or aerobic exercises.</td>
</tr>
<tr>
<td></td>
<td>Aerobic exercises</td>
<td>1</td>
<td>Non significant decrease in distance covered</td>
</tr>
<tr>
<td></td>
<td>Specific drills, PAP</td>
<td>1</td>
<td>Non significant decrease in distance covered</td>
</tr>
<tr>
<td>Collegiate/Recreational</td>
<td>Rest/ Passive heating</td>
<td>1</td>
<td>Decrease in sprint performance after rest condition.</td>
</tr>
<tr>
<td></td>
<td>Aerobic exercises</td>
<td>1</td>
<td>No changes in sprint performance after running exercises</td>
</tr>
<tr>
<td></td>
<td>Specific drills, PAP</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

Abbreviations: PAP: post activation potentiation, RWU: re-warm-up, CMJ: countermovement jump

*: Performance changes after interventions were compared with pre-test (before or during half-time) and between conditions.