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Acute effect of different warm-up interventions on neuromuscular performance of recreational soccer players

Efeito agudo de diferentes intervenções de aquecimento pré-exercício sobre o desempenho neuromuscular de jogadores amadores de futebol

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ABSTRACT: Pre-exercises interventions are frequently implemented in order to maximize athletic performance. In this sense, the aim of this study was to evaluated the effect of three distinct pre-exercise interventions on acute neuromuscular performance in recreational soccer players: 1) parallel squat; 2) static stretching; and 3) ballistic stretching. After all interventions, participants performed a flexibility evaluation (sit-and-reach-test), followed by a squat jump, a counter-movement jump and a 30 meter-sprint test. A one-way analysis of variance revealed: a) a significant decrease in jumping performance was induced by both Stretching conditions when compared to the parallel squat intervention; b) a significant increase in lower limb flexibility after both stretching interventions when compared to parallel squat. In conclusion, it is suggested that a pre-exercise intervention comprised of stretching exercises acutely increase flexibility, while may interfere in jump performance in recreational athletes.

Key Words: Jumping; Postactivation potentiation; Sprinting; Stretching.

RESUMO: Intervenções pré-exercício são frequentemente adotadas para maximizar o desempenho atlético. Nesse sentido, o objetivo deste estudo foi avaliar o efeito de três diferentes intervenções pré-exercício sobre o desempenho neuromuscular de jogadores de futebol amadores: 1) agachamento paralelo, 2) alongamento estático e 3) alongamento balístico. Após as intervenções, os participantes realizaram a avaliação de flexibilidade (teste de sentar e alcançar) e, em seguida, o salto com agachamento, o salto com contramovimento e o teste de velocidade de 30 metros. Os resultados da ANOVA one-way revelaram: a) redução significante no desempenho do salto para ambas às condições de alongamento quando comparadas ao agachamento paralelo e b) aumento significante da flexibilidade dos membros inferiores após ambas às intervenções de alongamento em comparação ao agachamento paralelo. Em conclusão, sugere-se que as intervenções pré-exercício compostas de exercícios de alongamento aumentam agudamente a flexibilidade, paralelamente, podendo prejudicar o desempenho de saltos de atletas amadores.

Palavras-chave: Salto; Potencialização pós-ativação; Velocidade; Alongamento.

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Introduction

Pre-exercise intervention is a common practice preceding training and competition aimed at maximizing performance[1] and reducing injury risk[2] during exercise. These interventions include appropriately designed warm-up, passive heat maintenance, postactivation potentiation (PAP), remote ischemic preconditioning, and, more recently, prior exercise and hormonal priming[1].

Muscle postactivation potentiation (PAP) is a phenomenon characterized by an acute increase in neuromuscular strength and power and, consequently, physical performance. A great deal of research has attempted to identify methods that optimally elicit PAP during pre-exercise routines[3-7]. The ability by which a conditioning activity (strategies to argument physical performance) can stimulate PAP mechanisms depends on the balance between fatigue and potentiation[7]. This balance is affected by factors including subjects' training experience (untrained, "resistance-trained" or high level athletes), rest period length post conditioning activity, and its intensity[7]. Conditioning activities aiming to enhance physical performance, especially in professional athletes, have been previously investigated. However, it is not clear if such strategies could maximize performance in recreationaly athletes[8]. In a previous study, Till & Cooke[8] reported no significant group PAP (dynamic and isometric maximal voluntary contractions) effect on sprint and jump performance after compared with a control warm up protocol. These authors also observed a large variation in individual responses (-7.1% to +8.2%) to PAP, indicating that this should be considered on an individual basis.

Another very popular preconditioning performed by athletes and physically active subjects is stretching[2]. For instance, static and ballistic stretching techniques have also been used acutely during pre-exercise routines as a mean to further maximize flexibility[2,9,10]. However, there is no strong evidence to indicate a protective effect of stretching on injury incidence[2,11,12]. Previous observations reported that stretching exercises may induce acute improvement in flexibility and hence might be recommended before athletic events or physical activities that require a large range of motion[14]. With respect to static stretching, previous evidence suggests that it might acutely impair force output and, therefore, induce a reduction in strength and power performance in team sports when stretching is performed immediately before competition[2,13-15]. On the other hand, the ballistic stretching method could be a more appropriate pre-competition option because it seems less likely to acutely decrease maximal strength[14,16].

Despite the widely-held belief that pre-exercise routines are essential for optimum performance, little scientific evidence supports their effectiveness[1]. The present study aimed to evaluate the effect of 3 different pre-exercise interventions (parallel squat exercise, and static and ballistic stretching exercises) on jumping and sprinting performance in recreational soccer players. The initial study's hypothesis was that the stretching interventions would acutely increase flexibility but impair neuromuscular performance. Furthermore, an additional hypothesis was that the parallel squat exercise would potentiate jumping and sprinting performance.

Method

Experimental Approach to the Problem

To determine the effects of various pre-exercise procedures on subsequent measures of performance, 15 young, physically active, were assigned to perform 3 different protocols on 3 separate occasions in randomized fashion: parallel squat exercise (PS); static stretching exercises (SS), and ballistic stretching exercise (BS). Each trial was separated by 4 days and subjects refrained from any lower body exercise for at least 48 h prior to the interventions. After performing the respective pre-exercise procedure, subjects rested for 5 min and then performed the following tests: a sit-and-reach-test, the squat jump (SJ) and counter-movement jump (CMJ) tests, and a 30 meter-sprint test (30 m-sprint test). A 2 min rest interval was afforded between each test.

Participants

Fifteen recreational college male soccer players with no resistance-training background (mean ± SEM: age: 21 ± 3 yr; height: 177.4 ± 5.9 cm; body mass: 76.5 ± 6.9 kg) volunteered to participate in the study. All participants demonstrated an ability to perform the PS with appropriate technique. The training routine consisted of 2 soccer training sessions per week and 1 official match. Training sessions consisted of soccer specific drills, small sided games, technical and tactical routines, and simulated matches. The Piracicaba Methodist University Ethics Committee (UNIMEP – 38/2012) approved all experimental procedures and written informed consent was obtained from each subject. Qualified individuals, who had received proper instruction on testing protocols administered the tests.

Procedures

The experimental procedures of this study is shown in Figure 1. The effects of three distinct pre-exercise interventions on subsequent neuromuscular performance were investigated. The participants (n = 15) were assigned to complete the 3 different pre-exercise interventions following a randomized crossover experimental design distributed 4 days apart. The parallel squat (PS), static stretching (SS), and ballistic stretching (BS) were implemented to assess their effect on the subsequent neuromuscular performance. In the control © situation, the individuals were kept seated for 15 minutes (same period of time used in all experimental conditions). Participants refrained from any lower-body exercises for 48 h prior to each intervention. After each intervention, participants took 4 min of passive rest and then performed the following 3 tests. The sit-and-reach-test, the counter-movement jump (CMJ) test and the 30m sprint were post each intervention. A 1-minute (1') a passive rest interval was allowed sit-and-reach test and the CMJ test as well between CMJ test and 30m sprint test. A 2-minute (2') passive rest interval was utilized between 30m sprints.

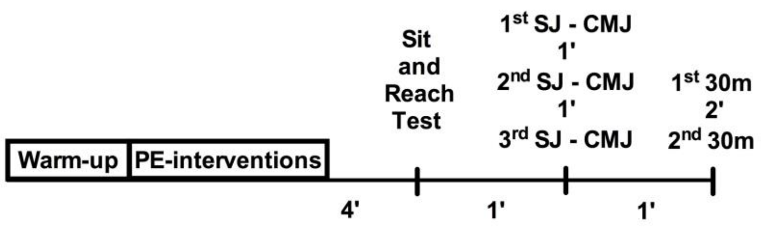

Figure 1. Experimental design

Pre-exercise Interventions

Parallel Squat (PS)

After 5 min of light jogging, subjects performed a specific pre-exercise involving 10 repetitions with a load equal to 50% of their body weight in the PS (90 degrees, knee joint) on the Smith machine. Subjects then rested for 5 min and performed 2 sets of 2 repetitions with a load equal to 100% of their body mass with 3 min rest between sets. The load intensity (50% of their body weight) was chosen to induce PAP. A previous study suggested that moderate loads are effective to induce PAP[7].

Stretching Interventions

Static and ballistic stretching interventions adopted in the present study were similar to those employed in a previous study that aimed at observe the effects of these interventions on neuromuscular performance[10]. Briefly, after 5 min of light jogging, subjects performed 3 sets of 4 stretching exercises for the quadriceps and the hamstrings for ~ 15 min. The exercises used were: Exercise 1. Subjects sat on the floor with both legs straight. Afterwards they extended their arms and reached forward by bending to the waist as far as possible while keeping their knees straight to achieve a stretch of the hamstrings. A partner provided assistance to find a maximal stretching position. Exercise 2. Subjects stood on their right leg while holding on to a stationary object for support. They bent their left knee, brought their heel toward to the gluteus maximus, and grasped their ankle to achieve a stretch of the quadriceps and hip flexors. A partner provided assistance to find a maximal stretching position. After completing the respective stretching protocol, subjects repeated the procedure on the other leg. Exercise 3. Subjects laid supine on the floor and lifted their right leg up with a partner's assistance while keeping the left leg flat. The partner kept a hand on the right heel and the other hand on the right knee, to hold the leg straight. After completing the respective stretching protocol, subjects repeated the procedure on the other leg. Exercise 4. Subjects kneeled with the left leg forward and right leg back. They then grasped the dorsal surface of the right foot and lifted the foot toward their gluteus maximus to achieve a stretch of the quadriceps and hip flexors. A partner provided assistance to find a maximal stretching position. After completing the respective stretching protocol, subjects repeated the procedure on the other leg.

Static Stretching (SS)

Static positions were maintained for 30 s at maximal discomfort, and a 15 s rest interval was allowed between them.

Ballistic Stretching (BS)

The same initial procedures adopted for the static stretching intervention were followed for the BS protocol, but instead of holding the stretching positions for 30 s, subjects were required to bob in 1:1 s cycles for 1 min.

Evaluations

Sit-and-Reach Test

Subjects sat with their heels pressed against the testing board with knees extended and right hand placed over the left. They were then instructed to reach as far as possible along the measuring board and holding the static position. Three attempts were performed and the best score was used for statistical analysis.

Jumping Tests

The SJ and CMJ were performed using previously described methods[17,18]. Briefly, following a standardized warm-up, 3 SJ and 3 CMJ trials were performed in a randomized counterbalanced order on a jumping mat (Jump System Pro – CEFISE©, Brazil). The SJ was performed as a concentric only movement (i.e., no sinking down before the vertical jump) with hand placement on the hips to remove the effects of arm swing. For the CMJ test, the participants were instructed to assume a self-selected squat position from an initial standing position and performed a vertical jump keeping their hands placed on their hips as quickly as possible with maximal effort. While no restrictions were placed on the knee angle attained during the eccentric phase of the jump, participants were instructed to maintain straight legs during the flight. A rest period was provided between jumps (1 min). Maximal vertical jump height (in cm) was determined and the best attempt was used for analysis. The jump mat provided valid measures of jump height compared to a criterion system (r = 0.967)[18]. A pilot test indicated that the jump mat system also provides reliable measures (CVs < 2.0%).

30 meter-Sprint Test

The 30 m-sprint test involved a stationary start (0m) with the subject initiating the sprint after a start signal. The subject positioned the toe of his front foot on the start line. Two maximum sprints were performed with the best split time being retained for analysis. Subjects were instructed to wait until they felt completely recovered before performing the second sprint trial, which typically took no more than 2 min. Light gates with electronic timing (CEFISE©, Brazil) were positioned at the start (0m), 1 m, 10 m, and 30 m.

Statistical Analyses

Conventional statistical methods were employed in order to obtain means and standard deviations. The Shapiro Wilk test was used in order to verify data normality. A one-way analysis of variance (ANOVA) was performed to compare the differences in magnitude of changes (pre-post) between 3 pre-exercise strategies. If any interactions were found, a post-hoc Tukey test was employed to assess differences. Significance was set at 0.05. Cohen's formula for effect size[19] was used and the results were based on the following criteria: < 0.35 trivial effect; 0.35 – 0.80 small effect; 0.80 – 1.50 moderate effect; and > 1.5 large effect.

Results

Flexibility

Sit-and-reach test results are presented in Table 1. Lower limb flexibility was increased for both stretching interventions (with a moderate effect size noted; $d = 1.0$; $p < 0.05$) when compared to C.

Jumping Performance

The SJ and CMJ results are presented in Figure 2. Jumping (SJ and CMJ) performance was significantly reduced after SS ($p = 0.001$) and BS ($p = 0.006$) interventions when compared to PS intervention. After both stretching interventions (BS and SS), a trend was detected for a decrease in jumping performance with a moderate to large effect size noted ($d = -0.5$ to -1.0; $p = 0.06$) when compared to C. The PS intervention did not affect jumping performance ($p > 0.05$).

Table 1. Sit-and-reach test results post control (C), Parallel Squat (PS), Static stretching (SS) and Ballistic stretching (BS) pre-exercise interventions.

Interventions	cm
C (n=15)	29.1 ± 5.8[a]
PS (n=15)	29.8 ± 5.3[a]
SS (n=15)	34.6 ± 5.1
BS (n=15)	35.0 ± 5.5

[a]Represents significant difference ($p < 0.05$) from C group. Data present as mean ± SD.

Sprinting Performance

The 30 m-sprint (and partial times for 1m and 20m) results are presented in Figure 3. No change in sprinting performance (1m, 20m and 30m) was observed with any of the pre-exercise strategies ($p > 0.05$).

Discussion

The aim of this study was to evaluate the effects of 3 distinct pre-exercise interventions on acute neuromuscular performance in recreational soccer players. The main results were: a) a significant ($p < 0.05$) decrease in jumping performance was induced by both stretching conditions (BS and SS) when compared to the PS intervention; b) a tendency for decreased jumping performance was observed after both stretching interventions (BS and SS) (a moderate to large effect size; $d = -0.5$ to -1.0; $p = 0.06$) when compared to C and c) a significant increase in lower limb flexibility both stretching interventions (BS and SS) (a large effect size; $d = 1.0$; $p < 0.05$) when compared to C. The initial hypothesis that stretching would acutely impair neuromuscular performance was not confirmed. However, a moderate to large effect size was reported when comparing stretching interventions (BS and SS) to C, suggesting a negative effect of these interventions on jumping performance. The hypothesis that the PS would serve as a pre-conditioning activity that induced PAP was not confirmed in the present study.

The initial hypothesis that stretching would induce acute neuromuscular impairment was based on the results of previous studies[9,14,16,20]. A performance decrement observed post-stretching has been widely explained by a combination of mechanical and neural factors. Regarding neuromuscular aspects, static stretching results in a longer and more compliant musculotendinous unit leading to a decrease in motor unit activation[16]. Static stretching-induced performance decrement is particularly evident in maximal and explosive muscular efforts that play an essential role in a number of individual and team sports[9,10,16,20-22].

The present study used 4 out of 6 stretching exercises investigated by Bacurau *et al.*[10] for the hamstrings and quadriceps. These authors reported a decrease in maximal strength (assessed by a 1 RM leg press test) after static stretching; however, the ballistic method did not affect this outcome[10]. The authors concluded that static stretching is not recommended before athletic events or physical activities that require high levels of force[10]. In such events, the ballistic stretching would seem to be a more appropriate pre-exercise strategy. The proposed mechanisms whereby ballistic stretching induces acute strength improvement include an elevation in muscle and body temperature[20], stimulation of the nervous system, decreased inhibition of antagonist muscles[21], and an enhanced ability of the musculotendinous units to store and utilize elastic energy during motor tasks[22].

Despite the fact that stretching interventions adopted in the present study were similar (4 out of 6 exercises, same number of sets and same stretching interval – 30 s) to those in the aforementioned study[10], the current results indicate a small to moderate negative effect ($ES = -0.5$ to -1.0) of both SS and BS interventions on jumping performance. The possible discrepancies between studies may be related to the gender and training level of the participants. In the study of Bacurau *et al.*[10] the sample was comprised of resistance-trained women whereas this study investigated recreational college male soccer players with no regular resistance-training background. Considering these conflicting results, future studies should be conducted to investigate the influence of gender and training background on stretching-induced neuromuscular performance impairment.

On the other hand, and corroborating the initial hypothesis, both ballistic and static stretching increased lower limb flexibility. Acute stretching-related increase in flexibility may occur due to muscular and neural mechanisms.

Muscular aspects may be associated with the viscoelastic stress relaxation attributable to greater tendon elasticity and a decreased muscle viscosity, resulting in a decreased passive joint torque[23,24]. Neural mechanisms may include a decrease in the activation levels of muscle spindle reflex excitability, contributing to the acute increased range of motion[25]. It also has been postulated that stretching promotes an increased pain tolerance to further stretching via adaptations in nociceptive nerve endings, thereby enhancing range of motion[26]. With respect to the present study, it is not clear whether the improvement noted in flexibility from SS and BS methods was mediated by similar or different mechanisms; this requires further study.

Contrary to the initial hypothesis, no significant difference was found among the 3 pre-exercise interventions for the 30 m-sprint test performance. A recent meta-analytical review determined that the acute decrement in performance is related to the total duration of stretching, with the smallest negative effects observed with a stretch duration of ≤ 45 s[16]. In the present study, stretches were maintained for only 30 s at maximal discomfort. Thus, it can be hypothesized that this low volume of stimulation may have been insufficient to impair performance in the investigated population.

The current findings stand in contrast of those of Sayers *et al*.[9], who reported a decrease in 30 m-sprinting performance following static stretching[9]. Differences in results may be attributed to the distinct exercises employed and muscles groups stimulated. The stretching intervention in the study by Sayers *et al*.[9] involved targeted stretching of the plantar-flexors. It is possible that the sprint performance impairment reported by Sayers *et al*.[9] after stretching might be due to a decrease in the tendon elastic strain energy in the plantar-flexors. In fact, it is has been previously reported that as running speed increases, the contribution of tendon elastic strain energy to the positive work generated by the muscle tendon unit is significantly amplified for the soleus and the gastrocnemius[27]. Therefore, the static stretching of calf muscles may have negatively affected the functioning of the muscle tendon unit, ultimately leading to a decrease in sprinting performance. Moreover, subjects in the Sayers *et al*.[9] study were elite female soccer players, suggesting potential influences of gender and training background in the response to stretching interventions. Additionally, the authors did not evaluate the changes in range of motion. The acute increased range of motion observed in the present study may have contributed to an acute enhance in the stride length - an important component that positively impacts sprint performance[28] - and thus attenuated any negative effect on the sprint test.

Finally, the initial hypothesis that the PS intervention would acutely enhance performance was not confirmed. As previously mentioned, research has attempted to identify methods to maximally elicit PAP during pre-exercise routines[1,3-7]. It has been postulated that the efficacy of a pre-conditioning activity as performance enhancer depends on training status and the balance between fatigue and potentiation[4,7]. In an effort to determine if training status directly affects the response to PAP, Chiu *et al*.[4] compared athletes engaged in strength and power sports to recreationally-trained individuals. Over the course of 4 sessions, subjects performed rebound and concentric-only jump squats with 30%, 50%, and 70% of 1RM loads. Jump squats were performed 5 min and 18.5 min following control or heavy load pre-exercise routines. Heavy load pre-exercise intervention consisted of 5 sets of 1 repetition at 90% of 1RM back squat. Results showed that the heavy load pre-exercise routine had no effect on the subjects as a single sample. However, when percent potentiation was compared between groups, force and power parameters were significantly greater for athletes. The authors concluded that PAP may be a viable method of acutely enhancing strength and power performance in athletic but not in recreationally-trained individuals. A recent study by Requena *et al*.[29] lends support to this hypothesis. In the study, 14 professional male soccer players with 12-15 years training experience performed a pre-conditioning activity consisting of a 10 s isometric maximal voluntary contraction intended to evoke PAP of the knee extensors. Results showed the pre-conditioning protocol improved performance, with a significant positive correlation found between PAP and jump height and a negative association noted with sprint time. When attempting to reconcile discrepancies in findings between studies, it can be speculated that the sample of recreational college soccer players in the present study may not have been sufficiently trained to reap the benefits of the pre-conditioning activity. On the other hand, in a previous study[8], conducted in academy soccer players, both dynamic and isometric maximum voluntary contractions, used as conditioning activities, failed to maximize sprint and jump performance. These results are in line with the current results, indicating that training status might a determining factor for PAP occurrence.

Additionally, it has been proposed that 2 main mechanisms are responsible for PAP: the phosphorylation of myosin regulatory light chains and the increase in the recruitment of higher threshold motor units[30]. In the present study, the subjects body mass was used as a parameter to determine the intensity of the conditioning activity. This choice was based on recent observations that potentiation was optimal following sets performed at moderate intensities[7]. Given evidence that untrained individuals are not able to recruit the entire motor unit pool during activities requiring high-force production[31], it is reasonable to speculate that the moderate intensity pre-conditioning intervention was not appropriate for potentiating recruitment of higher order motor units.

Conclusion

In conclusion, the results of this study suggest that both SS and BS can increase flexibility of recreational soccer players. Regarding jumping performance, a small to moderate negative effect was detected after both stretching interventions. In addition, these pre-exercise procedures did not negatively affect sprinting ability, possibly due to an acute increased range of motion contributing to greater stride length. Based on these observations, future studies should investigate the acute effects of different stretching protocols on the stride length, rate and its impact on sprinting performance. The PS with 100% of body mass did not induce to PAP, possibly due to the low training level in the sample population. Considering that recreational athletes with no resistance-training background are not able to fully recruit the highest threshold motor units, it is possible that higher intensity pre-conditioning activities would be necessary to elicit acute performance enhancements.

Practical applications

A pre-exercise intervention involving stretching exercises can acutely increase flexibility while interfering in jump performance. It is, therefore, important that strength and conditioning coaches consider the needs of the athlete in concert with the demands of a given sport when determining whether to include stretching exercises as part of the warm-up. In addition, coaches should be aware that pre-conditioning activities aiming to induce PAP seem to be dependent on a complex interaction of several factors, including the intensity of load, repetitions, rest interval, and the athlete’s training status.

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