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Original Article

The acute effects of combined foam rolling and static stretching program on hip flexion and jumping ability in soccer players.

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Abstract
The aim of this study was to investigate the effect of a combined program involving static stretching (SS) and foam rolling (FR) on hip flexion (Range of Motion-ROM) and jumping ability of soccer players. 24 amateur soccer players (age 21,73±0,87 years, height 179±0,53 cm and body mass 77,06±5,74 kg) divided in two groups: the control group which performed only short duration SS (10 sec) in quadriceps, hamstrings, adductors and gastrocnemious muscles and the experimental group which performed a combined program that included SS with the same duration and 30 sec FR in the same muscle groups. The participants were measured in the hip flexion (ROM) and the jumping ability was assessed with countermovement jump (CMJ) with the arms akimbo, and countermovement jump with free arms (CMJFREE). Two-way repeated measures analyses of variance revealed no significant difference between the two groups in any variable. However, there were observed significant differences between the pre-and post-intervention measurements in ROM and CMJ performance. These findings suggest that SS of short duration does not influence negatively the ROM and the jumping performance, and that a combined program with SS and FR also induces an improvement.
Key words: Self-myofascial release, flexibility, explosive power, warm-up

Introduction

The warm-up in individual or team sports, such as soccer, is considered to be an acceptable process (Bishop, 2003) and also necessary due to its positive effect on the performance increase and the reduction of injury risk (Young & Behm, 2002). Performance depends on numerous factors related to technique, tactic, physical condition, cognitive functions, etc. (Stölen, Chamari, K., Castagna & Wisloff, 2005). Soccer is characterized by an alternating rhythm (Ekblom,1986), which includes high intensities, many sprints, accelerations – decelerations, jumps, changes in direction (Little & Williams, 2006) and requires good joint flexibility. Generally in athletes, and especially in soccer players, good flexibility seems to have a positive effect on motor dexterity, neuromuscular coordination, motion precision and allows power generation through a larger range of motion (ROM) (Van Gyn,1984). Moreover, good joint flexibility has a positive effect on jumping ability, due to the better contact of the feet to the ground and the extra gain from the countermovement of the lower limb muscles (Galazoulas, 2017).

Coaches want soccer players to have increased ROM on their joints, without negative effects on the crucial elements for their overall performance in a game (sprint, jump, accelerations - decelerations, etc.). Static stretching is considered to be an effective way to increase joints' ROM (Mohr, Long & Goad, 2014; Škarabot, Beardsley & Štirn, 2015; Zakas, 2005), but the majority of researches shows a performance decrease in the explosive type motor actions (Kyranoudis et al, 2018; Vasileiou, Michailidis, Gourtsoulis, Kyranoudis & Zakas, 2013) and leg power (Faigenbaum et al, 2006), after their application. For this reason, in recent years, alternative ways for ROM enhancement have been applied, such as self-myofascial release (SMR) using foam rollers (FR) (McDonald et al, 2013). This technique is based on the logic of massage and appears to cause muscle tension release, increasing flexibility and consequently increasing ROM (Murray, Jones, Horobeanu, Turner & Sproule, 2016). Flexibility reduction is caused by a stiffness increase of the soft tissues, the joint capsules, the muscles and the fascia that surrounds them (Couture, Karlik, Glass & Hatzel, 2015). The fascia is a connective tissue, which when injured, inactivated or inflamed, causes a decrease in strength or endurance (Sullivan, Silvey, Button & Behm, 2013). The SMR using foam rollers helps to stretch a tight fascia (Barnes, 1997). The pressure exerted by the body weight through the foam roller in the soft tissue increases the temperature of the fascia, which takes a more fluid-like form (a thixotropic property of the fascia), causing the breakdown of fibrous healing between

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the fascia layers, due to injury or inflammation, and restoring the extensibility of soft tissues (McDonald et al, 2013).

In the last few years, a field of research has been developed concerning the influence of FR use in the athletes' warm-up (Junker & Stöggl, 2015; McDonald et al, 2013; Madoni, Costa, Coburn & Galpin, 2018; Miller & Rockey, 2006; Mohr et al., 2014; Murray et al, 2016; Škarabot et al, 2015) in various fitness properties, such as flexibility and strength, with contradictory findings. Junger & Stöggl (2015) observed improvement in flexion of the hamstrings after a 4-week intervention program, where participants performed 3 x 40 sec FR in the posterior femurs, 3 times per week. In contrast, Miller & Rockey (2006) did not found differences in ROM after an 8-week FR intervention program in the same muscle groups. Other researchers applied FR protocols to examine their acute effect on joint flexibility, with also conflicting results (Couture, et al, 2015; Healey, Hatfield, Blanpied, Dorfman & Riebe, 2014; McDonald et al, 2013; Madoni et al, 2018; Murray et al, 2016). McDonald et al (2013) observed an increase of 12.7% and 10.3% in knee ROM, after 2 min and 10 min intervention, respectively, and a similar increase in hip flexion ROM was found by Madoni et al (2018), after 3 sets of 30 sec FR in the hamstrings. In contrast, Couture et al. (2015) did not notice significant differences in passive knee extension, either after long duration rolling (4 x 30 sec) or short duration (2 x 10 sec). Similarly, Murray et al (2016) found no significant difference in hip flexor ROMs after 60 sec rolling of the hamstring muscles.

Concerning static stretching, the findings are controversial as well. Although static stretching is part of the warm-up for many years and its potential limitation or abolition (especially for those who are familiar with its use) may have a negative psychological effect (Young, 2007), several studies indicate a decline in jumping performance after the application of static stretching (Curry, Chengkalath, Crouch, Romance & Manns, 2009; Healey et al, 2014; Jones, Brown, Coburn & Noffal, 2015; Taylor, Sheppard, Lee & Plummer, 2009).

All of the above studies investigated separate the effect of FR or static stretching use, either on ROM or jumping ability. In the few studies, where a combination of FR and static stretching was used (Mohr et al, 2014; Škarabot et al, 2015), an increase in hip and ankle flexion ROM was observed. However, to the best of our knowledge, there are no studies about the effect of a combined FR and static stretching program on ROM, especially on jumping ability.

Thus, the aim of this research was to study the acute effect of a combined FR and static stretching program on the hip joint flexibility and the jumping ability of amateur soccer players. We hypothesized that a combined program with FR and static stretching induces a greater improvement of ROM and jumping ability, in comparison with a program which includes only static stretching.

Materials and Methods

Participants

Twenty - four amateur soccer players divided in two groups (control and experimental) as shown in Table 1. All the participants were without musculoskeletal injuries for the last 3 months and voluntarily participated in the current study, which took place in the middle of the season (March). They also were trained at least 3 times per week, 90 min per training session and played 1 game each week. They were informed of the aim of the study, its benefits and risks, and they signed an informed consent of participation in the study, which was approved by the university's institutional review board and ethics committee. All the procedures were in accordance with the Helsinki's declaration.

Table 1: Participants characteristics at baseline testing*.

	Control group	Experimental group
N	11	13
Age (years)	21.7±1.1	21.6±0.7
Height (m)	1.7±0.5	1.7±0.5
Weight (kg)	76±4.6	77.8±6.8

*Values are presented as mean ± SD.

Procedure

The participants visited the laboratory 3 times in 3 consecutive weeks. The measurements were done the same day and the same hour each week, at least 72 hours after a game in order to limit its effect. The players did not participate to any workout or activity 48 hours before the measurements. At the first visit, anthropometric measurements were done and the participants were familiarized with the protocols. At the second visit, each participant performed 5 minutes warm-up on the cyclometer in 74 Watts (1.5kg, 50rpm, Monark cycle) (Couture et al, 2015) and then performed the baseline measurements in the following order: Hip flexion ROM, countermovement jump (CMJ) with the arms akimbo and countermovement jump with free arms (CMJ FREE). After the second visit, the participants were matched according to their performance and each matched pair was randomly assigned to the experimental or to the control group. At the third visit, the participants performed the last measurements. Each participant of the control group performed 5 minutes cycling and after 30 seconds of relaxing executed static stretching on specific muscles. After 30 seconds, the ROM in the hip flexion was measured and then 2 CMJ and 2 CMJ FREE were performed. A 30 second break was between the jumps. Each participant of the experimental group performed the same program as the control group, and additionally, immediately after cycling, performed foam roller on the same muscle groups for 30 seconds. The procedure seems in Figure 1.

Stretching and foam rolling

Each participant of the control group performed static stretching in quadriceps, hamstrings, gastrocnemius and adductors. The stretch lasted 10 seconds for each limb, without a break when changing the legs. An interval of 20 seconds had been mediated when changing the muscle group. Stretching exercises are presented in Table 2. The short duration of the stretches was chosen to keep up with the daily training habits of the players.

The participants of the experimental group performed, in addition to the static stretching, 30 sec foam rolling per muscle group in the same muscles. The duration of 30 seconds is in alignment with other investigations (Healey, 2014; Jones et al, 2015). The foam rollers (FRs), which were used, were of different dimensions (Power Force FR 60X14 cm-BR-2010 for rolling in the hamstrings, quadriceps and gastrocnemius and Amila 33X13 cm FR-48197- for adductors). Each participant started rolling on the FR in the hamstring muscles, followed by rolling the gastrocnemius and then the quadriceps. The participants rolled simultaneously on both legs, as described in the Jones et al (2015)'s protocol, while in the last exercise (adductors) they rolled for 30 seconds alternatively in each adductor without an intermediate break when changing the legs. Roller exercises are presented in Table 3.

Figure 1: Research design of the experimental protocol.

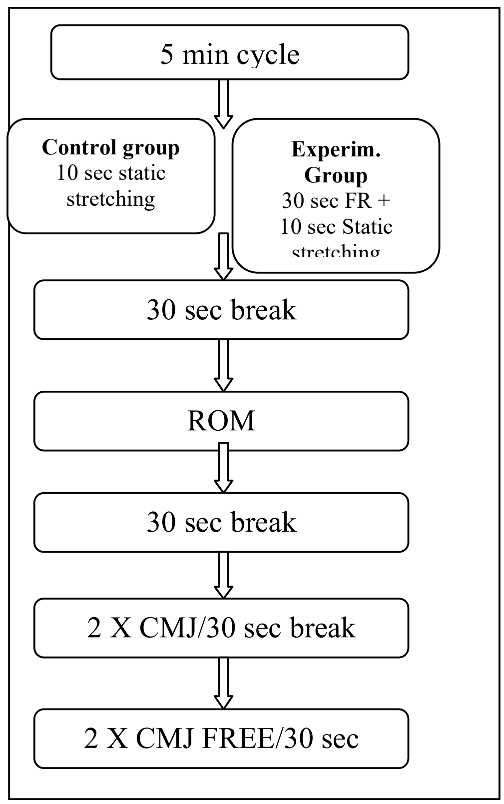

Table 2: Static stretching exercises[1]

Target muscles	Exercise
Quadriceps	Participants from the upright position touching with one hand on the wall for balance, grasped the ankle with the ipsilateral hand and attempted to touch it in the gluteus muscle.
Hamstrings	Participants from the upright position stepped one foot forward while bending the other leg. From this position they tried to touch the toes with both hands.
Adductors	Participants stood with feet spread apart. They leaned one knee on one side and held the opposite leg straightened without moving their feet.
Gastrocnemious	Participants touched the wall with their hands and elbows extended and extend one leg backward with the heel on the ground. They pressed the wall so they feel the stretch in their calf.

[1] All stretches were performed by both legs in an alternate order

Table 3: Foam roller exercises[2]

Target muscles	Exercise
Quadriceps	Participants laid face down with the foam roller under their thighs and put their forearms on the ground in a planking position. They rolled the foam roller distally and proximally from the bottom of the hip to the top of the knee.
Hamstrings	Participants sat on the foam roller under the top of the hamstrings muscle and their hands placed behind their back. Limbs were extended in front of the body and participants started to roll from the ischial tuberosity to the popliteal fossa.
Adductors	Participants laid face down with the foam roller at a 45 angle against their inner thigh and put their forearms on the ground in a planking position. They Started at their groin area, roll back and forth slowly from the very top of their inner thigh to right above their knee.
Gastrocnemious	Participants sat on the foam roller under their proximal calves and their hands were placed on the ground with their fingers pointing toward their body. Limbs were extended in front of the body and participants started to roll distally and proximally from distal to the knee to proximal to the ankle.

[2] All foam roller exercises were performed by both legs at the same time except the adductors' exercise which were performed in an alternate order

Flexibility and jumping performance evaluation

All participants, of both groups, were initially evaluated for hip flexion, using the Myrin goniometer (Lic. Rehab. 17183 Solna, Sweden), following the instructions of Ekstrand et al (1982). The OptoJump photoelectric cells system (Microgate, Bolzano, Italy) was used for the CMJ akimbo test and CMJ free test. The Optojump photocell system shows excellent test-retest reliability for the estimation of vertical jump height with low concurrent validity (mean: 2.7%) and high intraclass correlation coefficients (mean: 0.985) (Glatthorn, Gouge, Nussbaumer, Stauffacher, Impellizzeri & Maffiuletti, 2011). In the CMJ akimbo test, each participant was standing between the photocells and holding both hands on the hips performed an arbitrary counter movement, followed, without a delay, by an upward movement, reaching the maximum height. During the execution of the jump, each participant took care to maintain full extension in the hip, knee, and ankle joints and to land between the photocells. For the CMJ FREE each participant was standing between the photocells, but the arms were free to move. During the descent phase of the jump the participants were dropping down in the countermovement position as previously, with maximum arm hyperextension. From this position, the ascent phase of jump was started, with a fast upward movement of the arms, maintaining full extension in the hip, knee, and ankle joints and taking care to land between the photocells.

Statistical analysis

All results are reported as mean ± SD and seem in Table 4. Two-Way repeated measures ANOVAs were used for the statistical treatment of the data (independent factor: GROUP, dependent factor: TIME). The assumption of normally distributed samples and the sphericity were verified using the Shapiro-Wilk test and the Mauchly test, respectively. The level of significance was set as $p < 0.05$.

Table 4: Mean ± SD for range of motion (ROM), countermovement jump (CMJ) and countermovement jump with free hands (CMJFREE) in both conditions for pre-and post-test.#

	ROM pre	ROM after	CMJ pre	CMJ after	CMJFREE pre	CMJFREE after
Control group (SS)	107,27±12,07	113,36±11,12*	37,07±3,12	38,25±5,20*	44,68±4,92	45,57±5,19
Experimental group (SS+FR)	107,23±8,65	114,69±9,02*	35,36±6,5	36,72±6,48*	43,29±6,84	43,79±6,19

#ROM: Range of Motion, CMJ: Countermovement Jump, CMJFREE: Countermovement Jump with free hands, Pre: Before intervention, After: After intervention, SS: Static Stretching, SS+FR: Static Stretching and Foam Rolling (Combined Program). *Significant Differences

Results

It was not observed any significant interaction between the two factors (GROUP and TIME) in any dependent variable (ROM: $F_{1,22}$= 0.274; p= 0.606, CMJ: $F_{1,22}$= 0.031; p= 0.861, CMJFREE: $F_{1,22}$= 0.189; p= 0.668). Moreover, in no one of the dependent variables was observed any significant difference between the control and the experimental group (ROM: $F_{1,22}$= 0.001; p= 0.975, CMJ: $F_{1,22}$= 0.524; p= 0.477, CMJFREE: $F_{1,22}$= 0.444; p= 0.512).

Significant differences between the two TIME measurements were found only in the ROM ($F_{1,22}$= 26.806; p< 0.05) (figure 2) and the CMJ ($F_{1,22}$= 6.265; p< 0.05) (figure 3), while no significant differences were observed in CMJFREE ($F_{1,22}$= 2,388; P= 0,137) (figure 4).

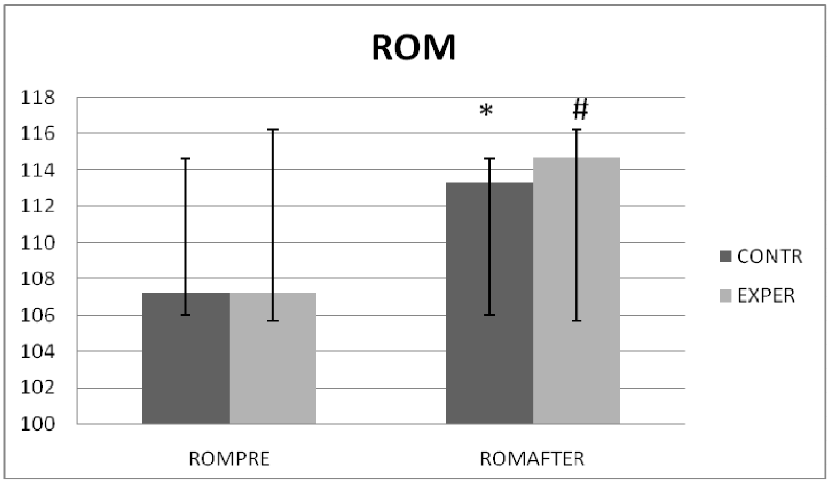

Figure 2: The effect of static stretching (black) and combined program (grey) on hip flexion ROM. * Significant differences with baseline measurements in control group (p<0,05).# Significant differences with baseline measurements in experimental group (p<0,05). Contr: Control group, Exper: Experimental group

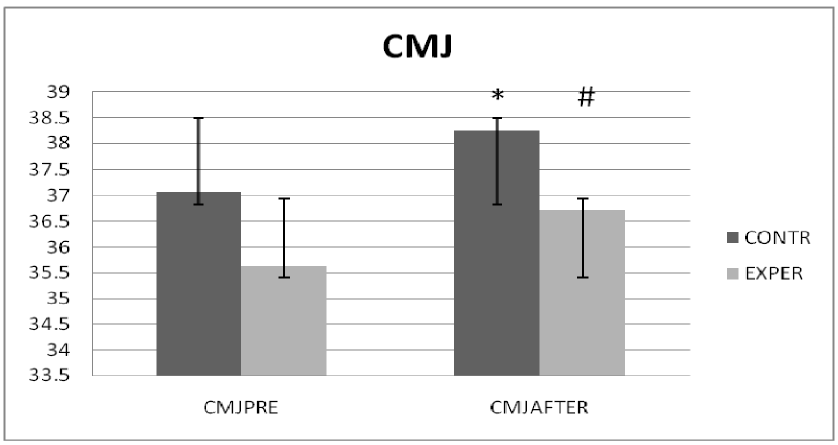

Figure 3: The effect of static stretching (black) and combined program (grey) on CMJ. * Significant differences with baseline measurements in control group (p<0,05). # Significant differences with baseline measurements in experimental group (p<0,05). Contr: Control group, Exper: Experimental group

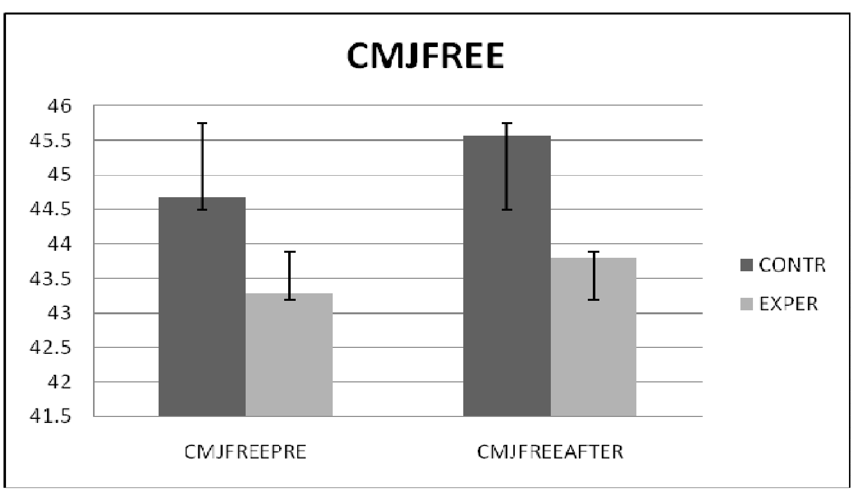

Figure 4: The effect of static stretching (black) and combined program (grey) on CMJ with free arms (CMJFREE) (p<0,05). Contr: Control group, Exper: Experimental group

Discussion

The main finding of the current study was that there were no significant differences between the control and the experimental group. Consequently, the experimental hypothesis that a combined program with FR and static stretching induces a greater improvement in ROM and jumping performance ability, in comparison with a program which includes only static stretching, was not verified. The results did not reveale any significant interaction between the factors "GROUP" and "TIME", while there was a significant main effect of "TIME" factor only in the ROM and CMJ in both groups, but not in the CMJ with free arms.

ROM in hip flexion increased significantly in both groups. The control group, which made only static stretches, also showed a significant increase in ROM, in agreement with previous findings (Curry, Chengkalath, Crouch, Romance & Manns, 2009; Murphy, Di Santo, Alkanani & Behm, 2010; Zakas, 2005), although the duration of the stretch was too short. According to Zakas (2005), the improvement of ROM after static stretching seems to be related to elongation of the muscle by dissociation of myosin cross-bridges from actin and not by the time of stretching or the number of repetitions. In the current study it was applied only 1 × 10 sec static stretching to 4 muscle groups and, to the best of our knowledge, this should be the only research with so short duration of static muscle stretching (Behm, Blazevich, Kay & McHugh, 2016).

Although the mechanisms that are activated during static stretching are not clear, the direct increase of the ROM after the application of static stretching could be attributed to the increased tolerance to the tension intensity (Magnusson et al, 1996), the reduction in connective tissue elasticity and viscosity (Morse, Degens, Seynnes, Maganaris & Jones, 2008) and the nerve inhibition of Golgi organs (Alter, 1996). However, the immediate response of ROM after a short stretch stimulus is probably due to the characteristics of muscle contraction, and not because of the involvement of the connective tissue (Hill, 1968; Magid & Law, 1985), the restrictive role of which is overestimated (Hutton, 1992). It is known that in the resting state of the muscle, the myofibrillar's myosin's cross-bridges are connected in a small proportion to actin's myofibriles (Hill, 1968). With the muscle elongation (static or dynamic), a portion of myosin's cross-bridges is dissociated from the corresponding actin's cross-bridges, leading to an increase in muscle length and hence to an increase of ROM (Hill, 1968; Magid & Law, 1985).

In the current study, a significant increase in ROM was also observed in the experimental group, which performed a combined foam roller and static stretching program. In the relevant literature are reported contradictory effects of the SMR application in the joints' ROM, both in chronic (Junger & Stöggl, 2015; Miller & Rockey, 2006) and acute adaptations (Couture, et al, 2015; Healey et al, 2014; Madoni et al, 2018; Mohr et al, 2014; Murray et al, 2016). However, to the best of our knowledge, only two investigations studied the use of a combined foam roller and static stretching program (Mohr et al, 2014; Škarabot, et al, 2015). Both show an improvement in ROM in hip flexion and in ankle's dorsiflexion, respectively, but none of them had the characteristics of the protocol of the current intervention. Mohr et al (2014) applied a combined foam roller and static stretching program, where the rolling duration was 3 x 1 min only in the posterior muscles and the static stretching lasted 3 x 1 min, while Škarabot et al (2015) used a 3 x 30 sec rolling and static stretching of the same duration, as well as a different type of foam roller. Nevertheless, despite the differences in the protocols between the above surveys and the current research, all showed an increase in ROM after a combined program. A possible explanation for the increased ROM may be the increase in the temperature of the muscle and the fascia which surrounds it (Mohr et al, 2014). The increase of the temperature before stretching has positive effects on the elastic and viscous properties of the connective tissue, reducing the resistance during stretching (Sapega, Quebenfeld , Moyer & Butter, 1981). Even Hutton (1992), who, as mentioned above, considers that the restrictive role of connective tissue is overestimated, recognizes this role towards the end of the movement. Obviously, with the foam roller application, there is a cross-bridge release and, in combination with static stretching, leads to an increase in the length of the muscle.

Another parameter that probably contributes to an increase in ROM, due to a combined foam rolling and static stretching program, is the thixotropic capacity of the fascia that surrounds the muscles. According to McDonald et al (2013) the fascia is made by colloidal substances and when it stays inactive, injured or inflamed, it creates cross-links or scar tissues, which limit the ROM. However, when it disturbed by thermal or mechanical stress, such as foam roller, these bonds are broken down, the fascia becomes soft and takes the form of gel. In addition, it becomes less resistant to stretching, leading to a larger ROM (Mohr et al, 2014).

The results also showed a significant increase in jumping ability in both, the control and the experimental group. This finding is in contrast with the majority of the investigations, where a performance reduction in explosive muscle efforts (Simic, Sarabon & Markovic, 2013), such as jumping, was recorded. However, on the other hand, is in agreement with other studies, where either does not observed a reduction after static stretching (Unick, Kieffer , Cheesman & Feeney, 2005) or is reported an improvement (Gonzalez-Rave, Machado, Navarro-Valdivielso &Vilas-Boas, 2009; Little & William, 2006). Nevertheless, the protocols used in previous investigations, were different from the protocol of the current research. Gonzales-Rave et al (2009) applied 3 x 15 sec static stretching, while Unick et al (2005) applied the same stretching duration followed by a 4-minute walk and the participants in the Little & Williams' survey (2006) performed progressively interval sprints after stretching.

Due to the fact that, in recent years, soccer players use short-duration stretches in their daily practice, static stretches of only 1 x 10 sec have been used in the current study. To the best of our knowledge, this should be the only research in the relevant literature with such short period of time. Thus, the jumping improvement of the amateur soccer players participated in the current study could probably be attributed to this short duration of the static stretching. This short duration is considered to mitigate the harmful effects of stretching (Behm & Ghaouachi, 2011), while stretches of long duration are associated with performance reductions (Zakas , Doganis, Papakonstandinou , Sentelidis & Vamvakoudis, 2006).

Although some studies used FR to examine their effect on the jumping ability (Healey et al, 2014; Jones et al, 2015), there are few surveys to assess the influence of a combined FR and static stretching program (Mohr et al, 2014; Škarabot et al, 2015). In the current study, an increase was also observed in the experimental group that performed a combined FR and static stretching program. It is known that increased body temperature influences positively the performance (Asmussen & Boje, 1945), through a reduction of viscous muscular resistance (Bishop, 2003). Self-myofascial release using foam rollers may increase the muscle temperature due to the increased temperature of the intramuscular tissue and the increased blood flow, causing changes in the viscoelastic properties of the muscles (Knight , Rutledge, Cox, Costa & Hall, 2001). The warm-up with cycling has probably also contributed to the increase of the body's and lower limb muscles' temperature. In addition, changes in the muscles' and fascia's thixotropic property lead to decrease in tissue viscosity, as previously mentioned, resulting in more tolerance to stretching (McDonald et al, 2013; Mohr et al , 2014). Moreover, the release of cross-bridges during stretch (Hutton, 1992) may lead to an increase of the muscles' length, enabling greater force production.

Nevertheless, in the current study it was not observed a significant difference in the height of the CMJFREE between the two measurements, both in the experimental and the control group. This finding is in agreement with previous studies (Healey et al, 2014; Jones et al, 2015), despite the fact that the CMJ tests used in some of these surveys were executed differently from those used in the current study. Only in Jones et al (2015) research, the participants performed CMJ with free arms. The lack of significant difference between the initial and final measurement in CMJFREE in both groups in the current study, could be attributed to the influence of the arms' movement. The arms' movement stores energy mainly to the shoulders and elbows, during the initial phase of the jump, and transfers this energy to the rest of the body during the final phase of the jump (Lees, Vanrenterghem & Clercq, 2004). However, in the current study there was no intervention regarding the arms and thus their dominant role during the jump was not affected by the applied protocol.

Conclusion

The findings of this research reveal that the use of a combined SMR program through FR and short duration static stretching improves hip flexion ROM and jumping ability of amateur soccer players and thus could be suggested for the warm-up in soccer. However, still 10 sec static stretch seems to improve ROM without having a negative impact on players' explosive abilities, such as jumping. Consequently, although a combined program with FR and static stretching improves ROM and jumping performance ability, this improvement is not statistically significant different from the effect of a program which includes only static stretching of short duration.

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