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ORIGINAL RESEARCH

COMPARING THE EFFECTS OF SELF-MYOFASCIAL RELEASE WITH STATIC STRETCHING ON ANKLE RANGE-OF-MOTION IN ADOLESCENT ATHLETES

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ABSTRACT

Background: Increased flexibility is often desirable immediately prior to sports performance. Static stretching (SS) has historically been the main method for increasing joint range-of-motion (ROM) acutely. However, SS is associated with acute reductions in performance. Foam rolling (FR) is a form of self-myofascial release (SMR) that also increases joint ROM acutely but does not seem to reduce force production. However, FR has never previously been studied in resistance-trained athletes, in adolescents, or in individuals accustomed to SMR.

Objective: To compare the effects of SS and FR and a combination of both (FR+SS) of the plantarflexors on passive ankle dorsiflexion ROM in resistance-trained, adolescent athletes with at least six months of FR experience.

Methods: Eleven resistance-trained, adolescent athletes with at least six months of both resistance-training and FR experience were tested on three separate occasions in a randomized cross-over design. The subjects were assessed for passive ankle dorsiflexion ROM after a period of passive rest pre-intervention, immediately post-intervention and after 10, 15, and 20 minutes of passive rest. Following the pre-intervention test, the subjects randomly performed either SS, FR or FR+SS. SS and FR each comprised 3 sets of 30 seconds of the intervention with 10 seconds of inter-set rest. FR+SS comprised the protocol from the FR condition followed by the protocol from the SS condition in sequence.

Results: A significant effect of time was found for SS, FR and FR+SS. Post hoc testing revealed increases in ROM between baseline and post-intervention by 6.2% for SS ($p < 0.05$) and 9.1% for FR+SS ($p < 0.05$) but not for FR alone. Post hoc testing did not reveal any other significant differences between baseline and any other time point for any condition. A significant effect of condition was observed immediately post-intervention. Post hoc testing revealed that FR+SS was superior to FR ($p < 0.05$) for increasing ROM.

Conclusions: FR, SS and FR+SS all lead to acute increases in flexibility and FR+SS appears to have an additive effect in comparison with FR alone. All three interventions (FR, SS and FR+SS) have time courses that lasted less than 10 minutes.

Level of evidence: 2c

Key words: Ankle, dorsiflexion, flexibility, self-massage, stretching

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INTRODUCTION

Increased flexibility, as defined by greater joint range-of-motion (ROM), is often desirable immediately prior to sports performance. Static stretching (SS) is commonly recommended for increasing flexibility acutely.[1] However, SS has been associated with acute reductions in performance in sporting movements,[1,2] which are not desirable. Self-myofascial release (SMR) is an alternative modality that has also been reported to increase flexibilty acutely.[3,4,5,6] Unlike SS, increases in flexibility following from SMR appear to occur without concomitant reductions in force production.[3,4,5,6,7,8] Additionally, with the growing popularity of SMR methods like foam rolling (FR), there is a pressing need for scientific investigation of their effects. SMR methods including FR and roller massage sticks have not only been shown to increase flexibility but also to reduce arterial stiffness, improve arterial function and improve vascular endothelial function[9] and reduce soreness,[6,10] which makes their use particularly interesting for both athletes and the general population.

Previous research has shown that SMR can increase flexibility acutely in untrained, adult subjects with no SMR experience.[3,4,5,6] However, no previous study has reported on the effect of SMR on acute flexibility in subjects with experience of using SMR tools, nor on the effects of SMR on acute flexibility in adolescent subjects, in athletes, or in those with resistance-training experience. Experience with SMR tools has been suggested as a potentially important modifying factor for the acute effects of SMR on flexibility. Curran et al[11] proposed that individual technique, rather than physical dimensions, might be important for determining the ability to apply pressure to the underlying tissue. It was therefore suggested that subjects with experience of SMR may be better at applying pressure and thereby able to gain greater acute effects on flexibility from its use. Equally, it is possible that experience with SMR may instead lead to acclimatization to its effects and consequently any subsequent acute increases in flexibility might be smaller.

While many athletes may benefit from increased flexibility at certain joints for particular purposes, it has been reported that swimmers may specifically benefit from increased ankle flexibility[12,13,14] and that this may improve performance. Therefore, methods to increase ankle flexibility in swimmers are of particular interest. Young et al[15] performed a systematic review on interventions that are effective over long--term periods but no similar review exists for acute effects. Nevertheless, it has been reported that SS is effective for acute increases in ankle dorsiflexion ROM.[3,16,17] Additionally, Halperin et al[3] also reported that SMR using a roller massager was able to induce acute increases in ankle dorsiflexion ROM. However, whether the acute effects of SMR and SS are additive in respect of either ankle dorsiflexion ROM or at any other joint has not been previously investigated. It is possible that performing both SMR and SS together may be superior to performing either modality alone for improving flexibility acutely. The only trial performed in which a combination of both SMR and SS was investigated did not explore passive ankle dorsiflexion ROM acutely. Rather, Mohr et al[18] compared the long-term effects of FR, SS and a combination of FR and SS on passive hip flexion ROM. Mohr et al[18] recruited 40 subjects with limited passive hip flexion ROM and randomly allocated them into either a control group or intervention groups who performed either SS, SMR or a combination for six sessions. A significant change in passive hip flexion ROM was found, regardless of treatment. In addition, the combined group displayed a significantly greater improvement than any of the other groups. These findings suggest that since SMR and SS demonstrated an additive effect over a long-term investigation, they may also be effective acutely, when compared with either SS or SMR alone.

How long acute improvements in flexibility following SMR last is unclear. Previous studies have shown that acute increases in flexibility persist for at least 10 minutes post-intervention.[3,5,6] However, Jay et al[6] found that there were no significant differences in flexibility at 30 minutes post-intervention between FR and a control. Thus, while it appears that improvements in flexibility last from 10 to 30 minutes, the exact duration is unknown. How long acute improvements in flexibility following SS last has been subject to more investigation but is equally unclear on account of conflicting reports. DePino et al[19] investigated knee extension ROM following a hamstring SS protocol at 1, 3, 6, 9, 15, and 30 minutes and found that there were no significant effects beyond three minutes. Halperin et al[3] showed that ankle dorsiflexion ROM remained increased 10 minutes post-SS intervention. Ryan et al[16] reported that ankle dorsiflexion ROM returned to baseline levels at 10 minutes post-SS intervention, regardless of the duration of the plantarflexor SS protocol (2, 4 and 8 minutes, respectively). How long acute improvements in flexibility following from a combination of SMR and SS last is unknown. The findings of Mohr et al[18] suggest that since the two treatment modalities may be additive in increasing flexibility in a long-term trial they may also be additive regarding the duration of acute increases in flexibility in comparison with either SS or SMR alone.

Since FR has never previously been studied in relation to SS in adolescents, in resistance-trained athletes or in individuals accustomed to FR, the primary purpose of this trial was to compare the acute effects of FR and SS and a combination of both (FR + SS) of the plantarflexors on passive ankle dorsiflexion ROM in resistance-trained, adolescent athletes with at least six months of FR experience. On the basis of previous research suggesting an additive effect of SMR and SS over a short-term period,[18] it was anticipated that FR + SS might be superior to FR and SS. The null hypothesis was therefore that there would be no difference between the interventions. Aditionally, since the duration of effects of FR, SS and FR + SS are unclear, a secondary purpose of this trial was to compare the duration of any acute changes in flexibility in each condition over four time points post-intervention (immediately post-intervention and after 10, 15 and 20 minutes). Again, since there are indications that an additive effect of SS and FR might exist, it was anticpated that the duration of FR + SS might exceed that of SS and FR alone. The null hypothesis was that there would be no difference between the interventions.

METHODS

Subjects

Eleven adolescent, trained swimmers were recruited (5 females and 6 males,age: 15.3 ± 1.0 years, height: 172.3 ± 8.6 cm, weight: 64.5 ± 10.3 kg) who were participating in 16 hours of swimming training, three hours of resistance-training, and at least 30 minutes of FR per week, for the six months prior to the commencement of the trial. To be included in the trial, the subjects had to be free from any ankle-related or lower-limb injury, as this may have influenced the mobility of the ankle joint. Since all subjects had a minimum of six months of resistance-training experience, they can be classified as intermediate resistance-trained according to American College of Sports Medicine (ACSM) definitions.[21] The parents of all subjects provided written consent prior to participation. The Ethical Commission of Faculty of Sport, University of Ljubljana, approved this study.

Experimental approach

A randomized within-subject design was used to explore the acute effects of SS, FR and a combination FR + SS, on passive ankle dorsiflexion ROM. The subjects used their dominant leg thoughout the study, which was determined by reference to the leg that they would kick a ball with. Each subject visited the gym in which they were accustomed to exercising on three separate occasions at similar times in the day (between 4 – 5 pm) to avoid diurnal variations, with a minimum of 24 hours between each visit. On each visit, the subjects performed one of the three interventions (SS, FR, and FR + SS). The order of the three interventions was randomized for each subject. Randomization was performed by blinded selection of paper tokens by the subjects upon which a number was written. Upon arrival for the first visit, all subjects selected a piece of paper from a container. The number provided the order of conditions to be followed for that subject. The container was supplied with the same number of pieces of paper for each permutation of conditions. Each intervention was performed barefoot and no warm–up activity was performed beforehand. Each visit began with a baseline measurement of passive ankle dorsiflexion ROM, which served as a control, following the procedure used for later measurements, as outlined below, and as shown in Figure 4. Subjects then proceeded with one of the interventions (SS, FR, FR + SS). Immediately post-intervention, passive ankle dorsiflexion ROM was measured. In order to assess the time course of improvements in flexibility, further measurements of passive ankle dorsiflexion ROM were also taken at 10, 15 and 20 minutes post–intervention, respectively.

Static stretching comprised a single plantarflexor stretch performed for 3 sets of 30 seconds in duration with a 15-second rest between sets. To perform this stretch, the subjects stood with one leg on the edge of a bench, extended the knee and dorsiflexed, pointing their heel towards the ground. During the stretch, the subjects were allowed to lean on the wall for balance (Figure 1). The subjects were instructed to stretch to the point of discomfort but not to the point of pain. This stretching protocol was based on that outlined in a recent study performed in untrained subjects.[3] However, it differed insofar as Halperin et al[3] instructed subjects to stretch the plantarflexors to a pain level on a scale of 7 out of 10. Foam rolling was also performed 3 sets of 30 seconds in duration with a 15-second rest between sets. In this way, the volume of work performed in the FR and SS conditions was equalized.The FR group used The Grid Foam Roller (Trigger Point Technologies, 5321 Industrial Oaks Blvd., Austin, Texas 78735, USA), which is composed of uniform cylinder with a hard, hollow inner core enclosed with a layer of ethylene vinyl acetate foam. This type of roller appears to produce more pressure on the soft tissue than traditional foam roller made out of polystyrene foam.[11] Foam rolling was performed in a seated position with the legs extended and the feet relaxed as shown in Figure 2 and 3. One leg was crossed over the other to allow more pressure to be directed over the plantarflexor being treated. The subjects were instructed to use their arms to propel their body back and forward, from popliteal fossa to achilles tendon, in fluid

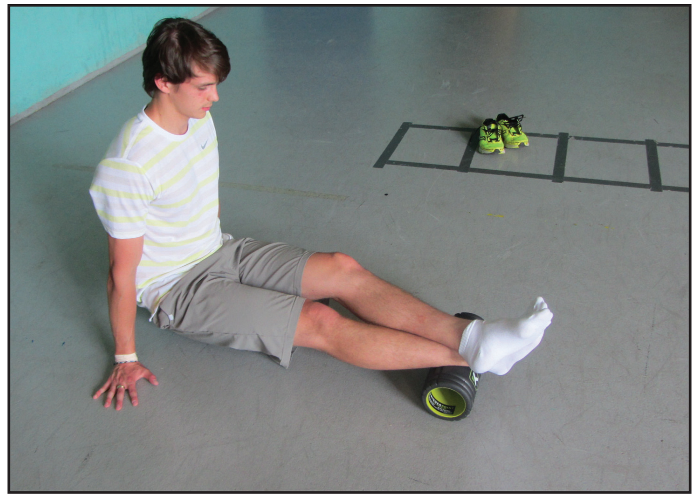

Figure 2. *Foam rolling start position*

Figure 3. *Foam rolling end position*

Figure 1. *Position of static stretching*

Figure 4. *Weight-bearing lunge test*

motions. They were also instructed to exert as much pressure on the foam roller as possible. Combination of foam rolling and static stretching consisted of the FR intervention directly followed by the SS intervention.

Measurements of passive ankle dorsiflexion ROM were taken by reference to a weight-bearing lunge test, as shown in Figure 4. It has been shown that this type of test has a high inter–rater and intra–rater reliability.[20] A measurement tape was placed on the floor perpendicular to the wall, in order to measure the linear distance between the big toe and the wall. Subjects stood on the tape with their big toe and heel. They were allowed to lean on the wall for better balance. Subjects were instructed to lunge their knee toward a wall in order to make contact with it. The foot was progresively moved away from a wall until the maximum ROM of the ankle was attained without heel lift. To control heel lift an elastic resistance band (Thera-Band, Hygienic Corporation, Akron, OH, USA) was placed under the subject's heel as described by Halperin et al.[3] The elastic resistance band was placed under tension by an experimenter. Where heel lift occurred, the elastic resistance band was pulled away and the results were declared invalid. Unlimited number of tries were allowed to attain the maximum passive ankle dorsiflexion ROM, as measured by reference to the linear distance between the big toe and the wall. Results from the test were rounded up to the nearest 0.5cm.

STATISTICAL ANALYSIS

Normality of the data were assessed using the Shapiro-Wilks test and sphericity was investigated using Mauchly's test. The results were analysed using SPSS (SPSS 17.0 for Windows Inc., Chicago, IL, USA). A 3 x 5 ANOVA (3 x condition – SS, FR, FR+SS, 5 x time – pre, post, 10, 15, and 20 minutes) for repeated measures was used. Differences were considered significant at an alpha level of 0.05. The Grennhouse-Geisser correction was used if the assumption of sphericity was violated. If an interaction was found the analysis was continued with one–way ANOVA. If significant differences were observed in the one-way ANOVA testing, post hoc testing involving pairwise t-tests with Bonferonni correction were performed. Descriptive statistics were reported for reference, including means and standard deviation (Mean $\pm$ SD).

RESULTS

Within conditions

A significant time effect was found for SS ($F(4,40) = 8.852$, $p < 0.05$, partial $\eta^2 = 0.470$), FR ($F(4,40) = 3.149$, $p < 0.05$, partial $\eta^2 = 0.239$) and FR+SS ($F(4, 40) = 9.277$, $p < 0.05$, partial $\eta^2 = 0.481$). Post hoc testing revealed increases in passive ankle dorsiflexion ROM between baseline and post-intervention by 6.2% for SS ($p < 0.05$) and 9.1% for FR+SS ($p < 0.05$) but not for FR. Post hoc testing did not reveal any other significant differences between baseline and any other time point for any intervention. The descriptive statistics for the increases in passive ankle dorsiflexion ROM with each intervention are provided in Table 1.

Between conditions

A significant effect of condition was observed immediately post-intervention ($F(2, 20) = 4.179$, $p \leq 0.05$, partial $\eta^2 = 0.295$). Post hoc testing revealed that FR+SS was superior to FR ($p \leq 0.05$) for increasing passive ankle dorsiflexion ROM. Post hoc testing did not reveal any other significant differences between conditions at any other time point.

DISCUSSION

The acute effects of FR, SS and FR+SS of the plantarflexors on passive ankle dorsiflexion ROM in resistance-trained, adolescent athletes with at least six months of FR experience were compared. The

Table 1. *Acute increases in passive ankle dorsiflexion ROM following interventions involving FR, SS and FR+SS at different time points*

	Pre (cm)	Post (cm)	Change at post (cm)	10 minutes (cm)	Change at 10 minutes (cm)	15 minutes (cm)	Change at 15 minutes (cm)	20 minutes (cm)	Change at 20 minutes (cm)
SS	14.5 ± 3.5	15.4 ± 3.2	0.9 ± 0.67	14.9 ± 3.4	0.4 ± 0.69	14.8 ± 3.5	0.3 ± 0.69	14.7 ± 3.3	0.2 ± 0.68
FR	14.5 ± 3.2	14.9 ± 3.4	0.4 ± 0.67	14.7 ± 3.4	0.2 ± 0.67	14.8 ± 3.2	0.3 ± 0.66	14.9 ± 3.1	0.4 ± 0.65
FR+SS	14.3 ± 3.2	15.6 ± 3.2	1.3 ± 0.65	15.0 ± 3.3	0.7 ± 0.67	14.9 ± 3.2	0.6 ± 0.66	14.7 ± 3.0	0.4 ± 0.65

Definitions: SS = static stretching; FR = foam rolling; FR + SS = foam rolling plus static stretching time course of these acute effects at four time points within a 20-minute period post-intervention was also investigated. It was found that FR, SS and FR + SS all lead to acute increases in flexibility and that FR + SS has an additive effect in comparison with FR alone. It was also found that all three interventions (FR, SS and FR + SS) had time courses that lasted less than 10 minutes. The current investigation was unique in several important respects: the additive effect of SMR and SS has not previously been explored and SMR has not previously been studied in adolescents, in resistance-trained athletes, or in individuals accustomed to using SMR techniques.

Comparison of FR, SS and FR + SS

On the basis of previous research suggesting an additive effect of SMR and SS over a short-term period,[18] it was hypothesized that FR + SS might be superior to FR and SS for increasing passive ankle dorsiflexion ROM acutely. This hypothesis was partially supported, as the increase in passive ankle dorsiflexion ROM in FR + SS immediately post-intervention was significantly greater to that observed in FR alone. However, the increase in passive ankle dorsiflexion ROM in FR + SS was not superior to that observed in SS alone. Since SS has been associated with acute, undesirable reductions in performance in sporting movements,[1,2] while SMR has not[3,4,5,6,7,8], these findings may imply that it may be possible to perform a reduced volume of SS by supplementing with FR in order to achieve a similar increase in ROM. In turn, this may induce smaller decrements in performance measures for the same benefit to flexibility. However, the current investigation did not compare volume-matched SS, FR and FR + SS conditions and it is unclear how reducing the volume of SS and FR within the FR + SS condition would affect flexibility. Moreover, it is unclear how performance might be affected by volume-matched SS, FR and FR + SS conditions.

In addition, it is unfortunate that although the difference in the changes in passive ankle dorsiflexion ROM was statistically significant between FR + SS and FR, the standard error of measurement[22] (SEM) was 1.1cm. This indicates that a difference of ±2.1cm may be necessary to be confident about the accuracy of a single measurement. Moreover, the Minimum Difference[22] (MD) to be considered real was 3.0cm. Since the reported differences between conditions for the change in ankle dorsiflexion ROM were all less than the MD ($\leq$0.9cm), this may suggest that the differences that were observed may be the result of measurement error (or chance) rather than an effect of the specific condition undertaken.

Nevertheless, it is informative to compare the current results with those of other investigators. While no previous acute investigation has explored the additive effects of SMR and SS in comparison with SMR or SS alone, at least two trials have directly compared the acute effects of SMR and SS with one another. Halperin et al[3] compared the acute effects of roller massage and SS in 14 untrained subjects and found that both interventions led to significantly increased passive ankle dorsiflexion ROM. However, there was no significant difference between interventions. Howe et al[23] compared the acute effects of SS and FR on hamstring flexibility as measured by sit-and-reach performance in 10 untrained subjects. Again, there were no significant differences between groups although the increases in sit-and-reach performance were non-significant in both groups, which may indicate a lack of sufficient statistical power.

The way in which FR + SS might display an additive effect beyond that observed in FR is unclear. By the observation of an additive effect, it may be the case that the mechanisms by which SS and FR increase flexibility are different or it may be that the greater stimulus led to a bigger increase in joint ROM. While the mechanism by which SS increases flexibility has historically been subject to some controversy, many researchers now maintain that the predominant means by which SS exerts its effects are central rather than peripheral[24] and that increased stretch tolerance is the primary mechanism. Similarly, the mechanisms by which SMR are currently thought to be effective are also neural.[25] Indeed, increased stretch tolerance is one of the proposed mechanisms for improvements in ROM in a joint after a bout of massage.[26,27] A number of trials have investigated the acute effects of SS duration or volume on flexibility and have reported conflicting results. Some studies have reported greater increases with longer durations of SS,[28] while others have not.[29,30] In respect of SMR, only one trial has directly assessed the acute effects of different volumes of SMR on flexibility. Sullivan et al[4] compared the acute effects of four different volume interventions of hamstring roller-massage (either 5-second or 10-second durations and either 1 or 2 sets) on flexibility using the sit-and-reach test. Although there was a significant increase in sit-and-reach performance in all conditions, there was no significant difference between groups. There was a trend towards a dose-response effect with 10-seconds of roller-massager rolling being slightly more effective at increasing sit-and-reach performance than 5-seconds, irrespective of the number of sets. Other trials investigating single volumes of SMR have used longer durations and have reported successful increases in flexibility, including 2 sets of 30 seconds,[23] 3 sets of 30 seconds,[3] 2 sets of 60 seconds,[5] and 10 minutes.[6] It is therefore feasible that the greater duration of treatment (either FR or SS) was responsible for the current results. Future research could compare matched volumes of SS, FR and FR + SS in order to address this question directly.

Time course of FR, SS and FR + SS

On the basis of previous research suggesting an additive effect of SMR and SS over a short-term period,[18] it was hypothesized that the duration of FR + SS might exceed that of SS and FR alone. This hypothesis was not supported. Significant main effects for time for each of FR, SS and FR + SS were found but post hoc testing revealed that increases in passive ankle dorsiflexion ROM were only significant between baseline and immediately post-intervention and only in SS and FR + SS. There were no significant differences between baseline and measurements taken at 10, 15 or 20 minutes in any condition. While it seems likely that the increase in FR was also only significant immediately post-intervention and therefore that there was no difference between interventions in relation to the time course of effects, the possibility cannot be ruled out that the modalities differed in this respect. The absolute increase in passive ankle dorsiflexion ROM immediately post-intervention in the FR condition was 0.4cm, which was very similar to the increase observed by Halperin et al[3] of 0.46cm at 1-minute post-intervention (Dr. David G. Behm, email communication, May 31, 2014) and therefore the lack of significant findings may relate to a difference in the number of subjects used in the two trials (14 vs. 11 individuals) and the resulting difference in statistical power.

Several previous studies have explored the time course of increases in flexibility following an acute intervention of either SS or SMR alone but no previous trial has investigated a combined intervention as is reported here. Regarding the time course of the acute effects of SS on flexibilty, the current results differ from those of Halperin et al,[3] who reported increases that persisted up to 10 minutes post-intervention. However, the current findings are in agreement with those of Ryan et al[16] and DePino et al[19] who both found that increases in joint ROM returned to baseline within 10 minutes post-intervention with SS. Regarding the time course of the acute effects of FR on flexibility, the current results differ from those of Halperin et al,[3] who used a roller massager on the ankle plantar flexors and reported increases at 10 minutes post-intervention in addition to one minute post-intervention, and MacDonald et al,[5] who used a foam roller on the quadriceps and also reported increases at 10 minutes post-intervention in addition to two minutes post-intervention . However, the current findings are in agreement with those of Jay et al,[6] who also used a roller massager on the hamstrings and found that while flexibility was greater immediately post-intervention, the effects were lost after 10 minutes. For both SS and FR, there are various factors that could theoretically explain differences between trials, including the population, the precise measurement method used for joint ROM, the muscle group being treated, and either the nature, intensity, volume and method of application of the SMR tool, or the intensity and volume of the SS, respectively.

The current investigation recruited only adolescent subjects while the majority of previous researchers investigating the acute effects of SS or SMR on flexibility have tested young adult populations. Far fewer studies have explored the acute effects of SS in adolescents and, to the authors' knowledge, this investigation is the first to explore either the acute effects of SMR alone or in combination with SS in adolescents (mean age of 15.3 $\pm$ 1.0 years). Nevertheless, by reference to the limited literature that has explored the acute effects of SS in adolescents,[31,32] it appears that SS does lead to increases in flexibility, as it does in adult subjects.

The current investigation recruited resistance-trained subjects with at least six months of resistance-training experience, which classifies them as intermediates for these purposes.[21] Few previous researchers have explored the differences in acute effects between trained and untrained individuals following a SS intervention and no previous trial has compared the acute effects of SMR alone or in combination with SS between individuals of differing training status. It is therefore unclear to what extent training status might have affected the current results. It is interesting to note that when Abdel-aziem and Mohammad[33] compared the long-term effects of SS in trained and untrained subjects on active ankle dorsiflexion ROM, they reported that while flexibility increased significantly in untrained individuals, no similar effect was found in trained subjects. Whether this same disparity would be observed in respect of acute effects, however, is unclear.

Regarding the intensity of application of SS, instructions used in the current investigation indicated that the subject should stop at the point of pain, while Halperin et al[3] instructed their subjects to stretch to a level of 7 out of 10. This difference in stretching intensity might well account for the longer-lasting effects observed by Halperin et al,[3] although the literature directly comparing the acute effects of different intensities of stretching is conflicting. In a trial comparing intensity of stretching of the ankle plantarflexors with either 100% and 90% of intensity by reference to pain, Young et al[34] found no differences between conditions on the acute increase in ankle joint ROM. In contrast, Chagas et al[35] compared maximal SS and sub-maximal SS comprising four repetitions for the hamstrings of 15 seconds each. They reported that while the maximal SS conditiondis played a significant difference in respect of the acute increase in joint ROM from pre-test to post-test, the sub-maximal SS condition did not. More recently, Freitas et al[36] explored three different intensities of stretch measuredby reference to the maximal tolerable torque of the first repetition without pain: 50%, 75%, and 100%. They found that only the stretch at 100% of maximum tolerable torque increased joint angle ROM. Regarding the intensity of FR, the current investigation required the subjects to exert as much pressure on the foam roller as possible. In contrast, Halperin et al[3] instructed the subjects to apply pressure equivalent to a pain level of 7 out of 10, Jay et al[6] required their subjects to perform SMR with a moderate pressure, and MacDonald[5] instructed the subjects to place as much of their body mass as possible upon the foam roller. No previous investigations have explored the combination of SMR and SS interventions, nor have any other studies investigated the effects of intensity of SMR on acute increases in flexibility.

The amount of pressure exerted during SMR might be a function of the tool used and the muscle group. MacDonald et al[5] used a custom-made foam roller that was constructed of a hollow polyvinyl chloride (PVC) pipe covered in neoprene foam and treated the quadriceps. Jay et al[6] did not describe the exact nature of the SMR tool but described it as a foam roller and applied it on the hamstrings. Halperin et al[3] used a roller massager and applied it to the ankle plantarflexors, as in this study. The technique of foam rolling on the the quadriceps and hamstrings may allow the ability to apply a greater proportion of body mass to the foam roller and consequently a greater pressure to the underlying tissue.

Limitations

This study was limited in several important respects. Firstly, while the subjects were experienced in the use of FR, they did not have direct previous experience of the exact FR tool used in the trial, the The Grid Foam Roller. In the six-month period prior to the start of the trial, the subjects were accustomed to using harder and denser SMR treatment by using PVC pipes. Secondly, the number of attempts to achieve the maximum ROM of the ankle joint during the passive ankle dorsiflexion ROM test were not limited. Since Atha and Wheatley[37] reported that there exists a mobilising effect of repeated measurements of joint ROM, this may have led to an interference effect whereby those subjects who performed more attempts achieved greater increases in flexibility. Thirdly, SS was performed with an extended knee, which may have exerted a greater effect on the biarticular gastrocnemius and a lesser effect on the monoarticular soleus. In contrast, the weight-bearing lunge test of passive ankle dorsiflexion ROM used for measurement was performed with a flexed knee and ROM may have been primarily restricted by the soleus and not by the gastrocnemius. Therefore, it is possible that using a SS protocol with a flexed knee may have led to superior acute increases in flexibility. Fourthly, it is noted that throughout the measurement process the subjects were always aware of their result, which may have influenced the outcome. Fifthly, the raters were also always aware which treatment modality was used prior to the measurements being taken. Sixthly, no attempts were made to control the activity of the subjects in the days prior to the measurements. Since the subjects were measured on different days, there could have been differences in delayed onset muscle soreness between the subjects on the day of the measurements, which may have affected joint ROM. In this respect, it is important to note that on many days, the athletes were accustomed to performing a swimming session in the morning and resistance-training sessions were also performed on several days (but not every day) in the week. Seventhly, the current sample size was not chosen based upon a power analysis, although it was similar in size to most other similar studies.[3,4,5] Finally, it is noted that the subjects did not perform any general warm-up activity prior to the baseline measurements being taken.

CONCLUSION

The acute effects of FR, SS and FR + SS of the plantarflexors on passive ankle dorsiflexion ROM in resistance-trained, adolescent athletes with at least six months of FR experience were investigated. FR, SS and FR + SS all lead to acute increases in flexibility and FR + SS had an additive effect when compared with FR alone, although by reference to the SEM and MD, it could be that this difference is the result of either error or chance. All three interventions (FR, SS and FR + SS) had time courses that lasted less than 10 minutes. Future research should explore whether there are differences in the acute responses to FR, SS and FR + SS between subjects who are familar with FR and SS, respectively, as well as whether the additive effects of FR + SS are a consequence of the greater volume of treatment.

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