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Acute and chronic effects of foam rolling vs eccentric exercise on ROM and force output of the plantar flexors

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Abstract:

Foam rolling and eccentric exercise interventions have been demonstrated to improve range of motion (ROM). However, these two modalities have not been directly compared. Twenty-three academy soccer players (age: 18 ± 1; height: 1.74 ± 0.08 m; body mass: 69.3 ± 7.5 kg) were randomly allocated to either a foam rolling (FR) or eccentric exercise intervention designed to improve dorsiflexion ROM. Participants performed the intervention daily for a duration of four weeks. Measurements of dorsiflexion ROM, isometric plantar flexion torque and drop jump reactive strength index were taken at baseline (pre-intervention) and at three subsequent time-points (30-min post, 24-hours post and 4-weeks post). A significant time x group interaction effect was observed for dorsiflexion ($P = 0.036$), but not for torque or reactive strength index. For dorsiflexion, there was a significant increase in both acute (30-min; $P < 0.001$) and chronic (4-week; $P < 0.001$) ROM for the eccentric group, whilst FR exhibited only an acute improvement ($P < 0.001$). Eccentric training would appear a more efficacious modality than foam rolling for improving dorsiflexion ROM in elite academy soccer players.

Introduction:

Injury incidence is often attributed to decreased lower limb flexibility (Backman & Danielson, 2011; Malliaras, Cook, & Kent, 2006; O'Sullivan, McAuliffe, & DeBurca, 2012). Specifically, impairments in dorsiflexion of the ankle have been identified as a risk factor for injuries such as anterior cruciate ligament injuries, patellofemoral pain syndrome, shin splints, Achilles tendinopathies (Rabin, Kozol, & Finestone, 2014), patellar tendinopathies (Backman & Danielson, 2011; Malliaras et al., 2006) and hamstrings injuries. Restrictions in dorsiflexion have been associated with increased valgus in landing, squatting and step down tasks (Rabin et al., 2014), as well as increased valgus and greater forces during landing (Halperin, Aboodarda, Button, Andersen, & Behm, 2014). Such kinematic and kinetic alterations may elucidate the link between dorsiflexion range of motion (ROM) and increased injury occurrence (Rabin et al., 2014). It is reasonable to suggest that impairments in ROM at joints such as the ankle may lead to undesirable movement patterns, reduced movement efficiency and lead to compensatory movement elsewhere within the kinetic chain (Mohr, Long, & Goad, 2014; Rabin et al., 2014). It may therefore be hypothesised that increasing dorsiflexion ROM is likely to be beneficial in reducing the occurrence of lower-limb injuries.

Static stretching is often implemented to increase ROM; however, a suggested limitation of static stretching is that it may lead to an acute decrease in force production (Couture, Karlik, Glass, & Hatzel, 2015; Halperin et al., 2014; MacDonald et al., 2013; O'Sullivan et al., 2012). Whilst short stretching duration (<30 seconds) are unlikely to confer the same deleterious effects as longer durations (i.e. >90 seconds), it would appear prudent to exercise caution when recommending static stretching prior to performance (Behm & Chaouachi, 2011). For this reason, additional techniques such as self-massage have been explored as modalities to improve ROM. Foam rolling (FR) is a self-massage technique demonstrated to be an effective means for increasing ROM (Beardsley & Škarabot, 2015; Cheatham, Kolber, Cain, & Lee, 2015). Furthermore, several studies have reported that self-massage does not negatively influence physical performance (Behara & Jacobson, 2017; Halperin et al., 2014; Healey, Hatfield, Blanpied, Dorfman, & Riebe, 2014; Jones, Brown, Coburn, & Noffal, 2015; MacDonald et al., 2013; Madoni, Costa, Coburn, & Galpin, 2018; Mikesky, Bahamonde, Stanton, Alvey, & Fitton, 2002). Two interventions have sought to determine the influence of self-massage on dorsiflexion ROM. Halperin et al. (2014) observed a 4.4% improvement ten minutes after stick massage of the triceps surae with no effect of the intervention on plantar flexion torque or rate of torque development. However, Škarabot, Beardsley, and Štirn (2015) did not report a significant improvement following FR of the triceps surae alone, but did report an additive benefit of stick massage and static stretching when compared to either modality in isolation.

Eccentric training is an alternative modality that also shows promise for inducing chronic improvement in ROM (O'Sullivan et al., 2012). For example, Mahieu et al. (2008) reported an increase in dorsiflexion of 5-6° following six weeks of eccentric training. Less is known however, about the acute effects of eccentric exercise on ROM. To the authors' knowledge, only two studies have sought to evaluate the efficacy of this modality on immediate changes. Nelson (2006) observed a 9.5° (± 6.9°) increase in 90/90 knee extension ROM following eccentric hamstring exercise. Jang, Kim, and Jang (2014) noted a 5-8° improvement in response to an eccentric calf protocol. To date, no investigations have sought to compare FR and eccentric exercise as modalities to improve ROM. Halperin et al. (2014) and Škarabot et al.

(2015) did not report significant differences in ROM changes between self-massage and static stretching interventions, although Škarabot et al. (2015) observed a positive effect for stretching but not for FR. Given that eccentric exercise may confer greater improvements than static stretching (Jang et al., 2014; Nelson, 2006), it may therefore be hypothesised that eccentric training would confer greater improvements in comparison to FR.

The primary objective within the current study was to compare the acute and chronic effects of eccentric training and FR on the dorsiflexion ROM. To the authors knowledge, these two interventions have not been compared directly. It was hypothesised that the eccentric interventions would induce larger acute and chronic improvements in dorsiflexion. In addition, the study sought to compare the effects of the interventions on performance parameters (maximal plantar flexion torque and drop jump reactive strength index). It was hypothesised that eccentric training, but not FR, would confer a benefit to these performance parameters.

Materials and method:

Participants

Twenty-three participants from female and male youth teams at a top-division Norwegian soccer club volunteered to participate in the study. Participants were required to be free from any lower limb injuries across the two months preceding data collection as well as participating fully in soccer training. All participants provided written informed consent; parents of participants under the age of 18 approved and signed consent forms. A previous and relevant investigation has shown improvements in ROM with a medium effect size (Monteiro, Cavanaugh, Frost, & Da Silva Novaes, 2017). Based on this, a minimum sample of 24 participants was determined from *a priori* power analyses (G*power 3.1 Heinrich-Heine Universität, Düsseldorf, Germany) based on effect size (d) of 0.6 and a power of 0.8 (Beck, 2013; Fritz, Morris, & Richler, 2012). The study was approved by the ethics review board of the relevant University.

Study design

A randomised trial with a pre-test, post-test design was used to compare the effects of FR and eccentric interventions on dorsiflexion ROM, plantar flexion torque and reactive strength index (RSI). During the initial familiarisation session, participants were randomly assigned to one of the intervention groups. Participants were assigned to either an FR group (n = 12; female: 6, male: 6; age: 18 ± 1; height: 1.73 ± 0.08; body mass: 68.9 ± 7.3 kg) or an eccentric group (n = 11; female: 5, male: 6; age: 18 ± 1; height: 1.75 ± 0.09 m; body mass: 69.7 ± 8.1 kg). Participants were coached through both intervention protocols and each of the performance tests during the familiarisation session.

The experiment was performed at the club's training grounds over the summer of 2017 and out of the competitive season. Participants completed three separate testing sessions on day 1 (baseline and 30-min post), day 2 (24-hours post) and day 28 (4-weeks post).

Foam rolling intervention

The FR protocol consisted of three bouts of 60 seconds of foam rolling across the gastrocnemius. Bouts were separated by 30 seconds. Participants were positioned sitting on the floor with the foam roller underneath their legs, with their hands on the ground to the side of their body. They were subsequently instructed to apply as much pressure between the gastrocnemius muscle and the foam roller as possible (SKLZ TRAINERroller®, SKLZ/Pro Performance Sports, Carlsbad, USA). Rolling was performed from the top of the calf down towards the insertion of the Achilles. The tempo of FR was not controlled, but was self-selected by the participant. Only the dominant leg was rolled, this defined as the leg they would choose kick a ball (Škarabot et al., 2015). The protocol was performed prior to the daily soccer training sessions for the four-week study duration. Following the coaching received in the familiarisation session, participants technique was not regularly monitored.

Eccentric training intervention

The eccentric training group performed a single-leg heel drop exercise (bodyweight-only), executed on a 0.3 m box. Three sets of 15 repetitions per leg were performed, with a 30-second rest duration. The calf of the dominant leg (defined above) was then loaded eccentrically when the participant lowered the heel beneath the level of the forefoot in a controlled manner and to the point of maximal perceived stretch (Ohberg, Lorentzon, & Alfredson, 2001). The participant was instructed to perform this downward movement in 6 seconds, which was self-timed. The opposite leg was used to assist the return to the original position. The knee was extended throughout the duration of each repetition. As with FR, the protocol was executed daily, prior to the soccer training sessions and for the four-week study duration. Following the coaching received in the familiarisation session, participants technique was not regularly monitored.

Testing sessions

Each testing session included measurements of dorsiflexion ROM, maximal isometric plantar flexion torque and drop jump RSI. Prior to testing, participants in both groups performed a standardised warm up. This consisted of 5-min cycle ergometry (80 W, 75-85 RPM), walking lunges (2 set x 5 repetitions each leg), deep squats (2 x 5) and supine glute bridges (2 x 5). Three measurements were taken for each test and tests were performed by the same investigator. The highest score for each test was recorded with only the dominant leg tested in each instance.

Joint range of motion

Dorsiflexion ROM was evaluated using a weight bearing inline lunge measured with incline goniometer (Baseline® Bubble® Inclinometer, White Plains, USA). Participants stood with their foot perpendicular to the wall and flexed their knee until it touched the wall in a straight line without the heel coming off the ground (Ekstrand, Wiktorsson, Oberg, & Gillquist, 1982). The foot was moved progressively away from the wall if the preceding trial was successful (i.e. knee touched the wall). The in-line weight-bearing ankle ROM test has been observed to have high inter-rater (r = 0.99) and intra-rater (r = 0.98) reliability (Halperin et al., 2014).

Plantar flexion torque

Peak plantar flexion torque was assessed by a maximal voluntary isometric contraction (MVC) performed on a force plate (MuscleLab^{TM}, ErgoTest Innovation, Porsgrunn, Norway). The protocol was performed in-line with the description of Unhjem, Flemmen, Hoff, and Wang (2016). Participants performed three to five submaximal warm-up contractions prior the maximal attempts. After the warm up, the participants were instructed to develop an MVC over five seconds; the task was repeated three times per participant with 30 seconds rest between trials. Each participant was verbally encouraged to apply maximal voluntary force. Visual feedback of the force trace was not provided to the participant during the trial.

Reactive strength index

Reactive strength index (RSI) was obtained using a single leg vertical drop jump. Participants were instructed to step, not jump, off a 0.2 m box on a force plate (MuscleLabTM, ErgoTest Innovation, Porsgrunn, Norway). Drop height was considered appropriate to facilitate short ground contact times during each jump (Maloney, Richards, Nixon, Harvey, & Fletcher, 2017). Participants dropped single legged from the box onto the force plate with the dominant leg, jumped immediately on ground contact and then landed from the jump with both feet. Hands were placed on hips throughout each jump and participants were instructed to minimise contact time whilst maximising jump height. Three submaximal jumps were performed as a warm-up with three maximal testing jumps then performed. Jumps were separated by 45 seconds. RSI was determined as flight time dived by contact time (Newton & Dugan, 2002).

Statistical analysis

To examine reliability, the standard error of measurement (SEM; calculated as $SD\sqrt{1-ICC}$) and intra-class correlation coefficient (ICC 3,1 (Shrout & Fleiss, 1979)) were determined for each of the three dependent variables. This was performed using the three measurements for each variable recorded at baseline. The minimal detectable change (MDC) was then calculated as $1.96(SEM)\sqrt{2}$ (Monteiro, Vigotsky, da Silva Novaes, & Škarabot, 2018).

A two-way mixed model analysis of variance (ANOVA) was used with one within (time) and one between (group) factor to determine the significance of any between-group and between-time differences for the dependent variables. Bonferroni post-hoc tests were performed where applicable. Individual responses to the interventions were reported as positive (improvement greater than MDC), negative (decease greater than MDC) or neutral.

Data was examined for normality using a Shapiro Wilks test. Data for plantar flexion torque and RSI violated normality, this was log transformed prior to ANOVA procedures. Mauchly's test for sphericity was violated in the ROM measures and was therefore run with the Greenhouse-Geisser calculations. The alpha level was set to $P < 0.05$ for all tests. Effect sizes were determined between time-points and between groups, these were calculated using Cohen's d (Cohen, 1988; Fritz et al., 2012). Effect sizes were interpreted as trivial 0-0.19, small 0.2-0.59, moderate 0.6-1.19, large 1.2-1.99 or very large ≥2.0. Statistical analyses were performed using SPSS version 21 for Mac (IBM, Chicago, USA). Data are presented as mean and ± SD unless otherwise stated.

Results:

ROM

The SEM for dorsiflexion ROM was 0.71°, reported with an ICC of 0.986 (95%CI: 0.963 to 0.994), and the MDC was 1.97°. Considering the whole cohort, dorsiflexion was significantly increased over the four-week duration of the study ($F(1.668,35.018) = 20.608$; $P < 0.001$; $\eta 2 = 0.495$), with no difference between groups ($F(1,21) = 0.006$; $P < 0.937$; $\eta 2 = 0.000$) (Figure 1). However, a significant time x group interaction effect was observed ($F(1.668,35.018) = 3.925$; $P = 0.036$; $\eta 2 = 0.157$).

*** Figure 1 Near Here ***

At baseline, there was no difference in ROM between groups ($P = 0.787$; $d = 0.11$). Acute (from baseline to 30-min post) improvements of 3.4° (9%; $P < 0.001$, $d = 0.54$) and 2.5° (7%; $P < 0.001$, $d = 0.47$) were observed following FR and eccentric exercise respectively. At 30-min post, between group differences in ROM were not significant, although a small effect size was reported ($P = 0.498$; $d = 0.27$). A chronic (from baseline to 4-week post) improvement of 2.6° (7%) was observed following FR, although this trend was not significant ($P = 0.090$; $d = 0.40$). This compared to an improvement of 5.1° (14%) following eccentric training ($P < 0.001$; $d = 0.96$). At 4-week post, between group differences in ROM were not significant, although a small effect size was reported ($P = 0.410$; $d = -0.27$).

Plantar flexion torque

The SEM for plantar flexion torque was 14.7 N.m, reported with an ICC of 0.994 (95%CI: 0.987 to 0.997), and the MDC was 40.6 N.m. Considering the whole cohort, plantar flexion torque did not increase significantly over the duration of the study

($F(3,63) = 0.994$; $P = 0.402$; $\eta 2 = 0.045$) (Figure 2). No effect of group ($F(1,21) = 0.001$; $P = 0.972$; $\eta 2 = 0.000$) or time x group interaction ($F(3,63) = 0.303$; $P = 0.823$; $\eta 2 = 0.014$) was observed.

*** Figure 2 Near Here ***

Reactive strength index

The SEM for RSI ROM was 0.17, reported with an ICC of 0.806 (95%CI: 0.587 to 0.914), and the MDC was 0.47. Considering the whole cohort, there was a significant increase in RSI over the duration of the study ($F(3,63) = 19.945$; $P < 0.001$; $\eta 2 = 0.487$) (Figure 3). No acute effect of time was observed (-2%; $P = 1.00$; $d = -0.04$), but a chronic improvement in RSI was reported (31%; $P < 0.001$; $d = 0.66$). No effect of group ($F(1,21) = 0.010$; $P = 0.923$; $\eta 2 = 0.000$) or time x group interaction ($F(3,63) = 0.610$; $P = 0.611$; $\eta 2 = 0.028$) was observed.

*** Figure 3 Near Here ***

Individual responses

Individual differences in both acute and chronic responses to the interventions were demonstrated (Table 1). For dorsiflexion ROM, a negative chronic response (defined as a change greater than the MDC) of the foam rolling intervention was observed in two participants. Five participants in both the FR (41.7%) and eccentric exercise (45.4%) experienced a negative acute response on plantar flexion torque, whilst two participants in each condition experienced a negative chronic response. For RSI, one participant recorded a negative acute response following FR.

*** Table 1 Near Here ***

Discussion:

The primary aim of this study was to compare the effects of FR and eccentric training interventions on dorsiflexion of the ankle; it was hypothesised that the eccentric intervention would induce larger acute and chronic changes for ROM. The current study reports that both interventions induced acute improvements in ROM. However, these improvements were only sustained following the eccentric training intervention. The study also aimed to evaluate the influence of these interventions on performance parameters related to the plantar flexors; it was hypothesised that eccentric training may confer an additional benefit to plantar flexion torque and drop jump RSI over FR. No change in plantar flexion torque was observed in either group, whilst both groups demonstrated chronic improvements in RSI. Nonetheless, changes in performance parameters were not consistent across participants and should be interpreted with caution. Moreover, the applied setting in which the investigation was conducted precluded a true control group (i.e. a group that received no intervention) and may be seen as a limitation.

The current study reported acute increases in dorsiflexion ROM of 3.4 ± 1.3° (9%; $P < 0.001$, $d = 0.54$) following SMR and 2.5 ± 1.4° (7%; $P < 0.001$, $d = 0.47$) following eccentric exercise. This compares favourably with previous investigations that have evaluated improvements at the ankle following FR. Škarabot et al. (2015) demonstrated an immediate improvement of 1.3 cm (9.1%; $P < 0.05$) of in-line lunge ROM when foam rolling was used in combination with static stretching, but saw no significant improvement with just foam rolling (0.4 cm; 2.8%). Also performing an in-line lunge test to evaluate ROM, Halperin et al. (2014) reported an improvement of 3.6% (~0.4 cm - estimated from figures; $P = 0.004$; $d = 0.24$) at 1-minute post stick massage and of 4.4% (~0.5 cm - estimated from figures; $P = 0.006$; $d = 0.26$) at 10-

minutes post. The findings of Halperin et al. (2014) somewhat contradict those of Škarabot et al. (2015), the latter observing that improvements in ROM had diminished by 10-minutes post-treatment. As the current study only evaluated ROM at 30-minutes post-treatment, the acute time-course of changes in ROM cannot be determined. Another important limitation within the current study was that the FR tempo was not controlled for. Thus, the possibility of pace-dependant outcomes cannot be discounted (Vigotsky et al., 2015).

Following an eccentric calf exercise protocol comparable to the current study, Jang et al. (2014) observed a 5-8° improvement in both active and passive dorsiflexion measured in the supine position. This is greater than the 2.5° (± 1.4°) improvement in dorsiflexion ROM demonstrated in the current study, although this was determined using a different type of assessment (weight-bearing lunge). Whilst Jang et al. (2014) reported similar improvements immediately following static stretching, beneficial effects in ROM were maintained throughout the post-intervention period (30-minutes), whereas gains following static stretching subsided. Such findings would indicate the benefits of eccentric training are likely to be longer lasting than those induced following static stretching. Also evaluating the acute effects of eccentric training, Nelson (2006) reported a 9.5° (± 6.9°) increase in 90/90 knee extension ROM following eccentric hamstring training (performed with a resistance band) and a 5.5° (± 4.5°) increase following static stretching.

It has been proposed that acute changes in flexibility induced by FR may be explained by increases in temperature and blood flow (Mohr et al., 2014), reported to increase the viscoelastic properties of muscle (Knight, Rutledge, Cox, Acosta, & Hall, 2001). Mohr et al. (2014) reported a positive effect of a FR intervention in hip flexion ROM, although re-analysis of the authors' results have questioned the significance of these findings (Vigotsky, 2015). It is likely that that the eccentric training interventions, as well as the pre-intervention warm-up, would have resulted in elevated muscle temperature in the current study. However, it has been reported that massage interventions may confer increases in skin, but not muscle, temperature (Hinds et al., 2004). As such changes were not monitored, this cannot be corroborated by this intervention. An additional explanation has been offered for acute improvements induced by FR. Thixotropic theory postulates that where heat or pressure is applied to the tissue, the tissue itself becomes less dense and more fluid, potentially facilitating greater ROM (Schleip, 2003a). FR creates sweeping pressure on the tissue and generates friction between the soft-tissue of the body and the foam roller, possibly facilitating thixotropic changes to occur (Mohr et al., 2014). This hypothesis is yet to be appropriately tested and substantiated by the literature.

Acute changes in ROM may not be explained by mechanical theories alone. The fascia of the body is profoundly innervated by mechanoreceptors that respond to myofascial manipulation, these mechanoreceptors are coupled with the central nervous system, and especially the autonomic nervous system (Schleip, 2003a, 2003b). Reviews evaluating the mechanisms by which massage techniques may work have suggested that the mechanical force may initiate a series of parasympathetic responses (Bialosky, Bishop, Price, Robinson, & George, 2009; Vigotsky & Bruhns, 2015), thus highlighting the potential for FR to effect the autonomic nervous system. Some of the mechanoreceptors that may be accountable for a change in ROM are the Golgi tendon organ and the Ruffini organs, both of which influence the alpha motor neurone and carry the potential to decrease the tone of surrounding tissues (Schleip, 2003a, 2003b). Whilst it is unlikely that FR will provide sufficient force to induce significant changes in muscle tone (Schroeder, Renk, Braumann, & Hollander, 2017), were inhibitory effects to be elicited, these are likely to be acutely detrimental to performance. Given that significant effects on performance (plantar flexion torque and RSI) were not reported in the current study, it is perhaps reasonable to suggest that the FR intervention did not influence muscle tone.

The current study reported that FR did not influence any significant acute changes in performance parameters of the plantar flexors. This is in agreement with several studies that have reported no effect of self-massage on performance (Abels, 2013; Behara & Jacobson, 2017; Halperin et al., 2014; Healey et al., 2014; Jones et al., 2015; MacDonald et al., 2013; Mikesky et al., 2002). Whilst decreases in peak knee flexor torque was reported following FR of the hamstrings by Madoni et al. (2018), impairments were similarly observed in a control group (no intervention) and thus no negative effect was concluded. Plantar flexor performance was evaluated in two of the aforementioned investigations. Halperin et al. (2014) demonstrated no effect of stick massage on isometric plantar flexion force, rate of force development and electromyography. Abels (2013) concluded no effect of a unilateral lower-limb foam rolling intervention on either RSI and jump height obtained during a single leg drop jump; this was accompanied by no change in the H-reflex, a commonly used surrogate indicator of motor excitability, although is one that is not without methodological limitation (Knikou, 2008). However, Abels (2013) utilised a within-subject design with the non-rolled leg serving as a control. Both limbs exhibited significant reductions in RSI (14% and 11% reductions for the intervention and control limbs respectively), with no difference between limbs (P = 0.69). Grabow et al. (2017) also examined drop jump performance, although this time following foam rolling of the quadriceps. The investigators observed a 1.3 - 9.6% reduction in RSI that although not statistically significant (P = 0.068), was reported with a moderate effect size (d = 0.84). It is therefore important to note that the potential for FR to negatively influence performance cannot be discounted.

In the current study, one individual in the FR group experienced a reduction in RSI exceeding the MDC. Moreover, a small effect size suggested a difference in the RSI at 30-min between the FR and eccentric groups (d = -0.20). Whilst this difference was not significant, it is prudent for coaches and practitioners to consider the potential harm of any intervention protocol. Acute changes in plantar flexion torque were much more variable in their response to the two interventions. In both groups, examples of positive and negative responders were observed. Given that participants in the current study had not been previously exposed to isometric testing prior to the familiarisation session, it is perhaps more likely that variations in this test are a consequence of random fluctuations in task performance. Also, participants were not able to view the force trace during testing, a suggested methodological consideration if seeking to maximise reliability (Gandevia, 2001).

The FR treatment did not elicit chronic improvements in ROM in the current study. To the authors' knowledge, the effect of chronic self-massage interventions on dorsiflexion ROM has not been evaluated. Several investigations have examined ROM measures pertaining to the hamstring, with benefits of self-massage typically conferred (Ebrahim & Elghany, 2013; Junker & Stöggl, 2015; Miller & Rockey, 2006; Mohr et al., 2014; Sherer, 2013). However, Mohr et al. (2014) reported larger improvements in passive knee extension following four weeks of static stretching versus foam rolling (d = 2.63 vs 1.81). Junker and Stöggl (2015) have also observed larger improvements with four weeks PNF stretching versus foam rolling. It would therefore appear that stretching interventions may be more effective for inducing chronic improvements in ROM than FR. However, it should be acknowledged that the specific execution of FR was not monitored during each session. As such, it cannot be dismissed that improper technique could explain why chronic improvements were not reported following the FR intervention.

Whilst static stretching has been demonstrated to be more effective than self-massage for achieving chronic improvements in ROM, resistance training may be more effective than static stretching (Morton, Whitehead, Brinkert, & Caine, 2011; Wyon, Smith, & Koutedakis, 2013). The current study reports that only the eccentric training group exhibited chronic (four-week) improvements in dorsiflexion ROM. The 5.1 ± 3.7° (14%; $P < 0.001$; $d = 0.96$) improvement that was observed following eccentric training is comparable to figures reported by Mahieu et al. (2008). Mahieu et al. (2008) demonstrated an increase of 5-6° (~9.5%) in dorsiflexion ROM (weight-bearing lunge) after a six-week training programme that also utilised an eccentric heel drop exercise. Kay et al. (2016) observed a larger 14.7° (92.7%) increase in passive dorsiflexion (assessed on an isokinetic dynamometer) following a six-week training protocol. The greater improvements observed by Kay et al. (2016) may be consequential of a more intense eccentric regimen; participants were subjected to eccentric lengthening through the dynamometer whilst attempting to maintain an isometric contraction. Nonetheless, eccentric training interventions appear capable of producing chronic improvements in dorsiflexion ROM, even when the technical execution of the intervention is not regularly monitored.

Conclusions:

The inclusion of either daily foam rolling and eccentric exercise (single-leg heel drops) interventions demonstrate the potential to induce acute improvements in dorsiflexion ROM in elite academy soccer players. However, eccentric training may confer sustained improvements in ROM where foam rolling may not. As such, coaches and practitioners may be better served by incorporating eccentric training modalities if seeking to improve dorsiflexion ROM.

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Figure Captions:

Figure 1 – Changes in dorsiflexion ROM (range of motion) across the duration of the intervention for the eccentric and foam rolling (FR) groups. * indicates significant change from baseline ($P < 0.05$).

Figure 2 – Changes in plantar flexion torque across the duration of the intervention for the eccentric and foam rolling (FR) groups.

Figure 3 – Changes in reactive strength index across the duration of the intervention for the eccentric and foam rolling (FR) groups. * indicates significant change from baseline ($P < 0.05$).