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Effects of Foam Rolling on Strength and Flexibility of Hamstring Muscles

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Abstract

Purpose: Foam rolling is frequently implemented in warm-up prior to an exercise session. The purpose of this study was to evaluate the acute effects of a short bout of foam rolling on maximal knee flexion strength along with active and passive hamstring flexibility. Methods: Fourteen healthy young participants were included in this within-subject randomized controlled trial. After warm-up a short bout (two sets of 60 s) of foam rolling was performed on the intervention leg (counterbalanced leg dominance) while the contralateral leg was used as a control. Measurement of peak knee flexion torque and hamstring passive and active range of motion were performed on both sides in counterbalanced order. An analysis of variance was conducted to evaluate differences between the two groups. Results: Our results did not show significant differences between the intervention and control leg for any of the assessed parameters. Conclusion: The main findings are that a short bout of foam rolling does not affect maximal knee flexion strength and that the foam rolling intervention does not further affect flexibility although hamstring passive flexibility increases following a warm-up. Based on our results we conclude that short bouts of foam rolling can be used prior to exercise, as they have no deleterious effect on muscle performance. Foam rolling before exercise should be recommended solely based on individual preference.

Keywords: *eccentric hamstring strength, isokinetic hamstring strength, hip range of motion, knee range of motion*

Introduction

A well-designed warm-up is necessary to prepare the athlete for upcoming loads and to enable maximal performance. Most commonly, it consists of general low-intensity aerobic activities, dynamic stretching exercises and sport specific drills (Safran et al., 1989). In addition, static stretching has been frequently used as part of warm-up as it increases range of motion (ROM) (Behm & Chaouachi, 2011). However, intensive static stretching prior to activity leads to a reduction in strength and power generation, thus hindering performance (Chaabene et al., 2019). It has been suggested that foam rolling (FR) could be an adequate alternative to stretching for warm-up.

In the past years, FR has become a very popular supplementary tool in strength and conditioning. FR is a form of myofascial self-release technique, in which the individual uses his bodyweight to apply pressure to the targeted muscle and rolls it over the FR (Peacock et al., 2014). The effects of FR have been studied as an addition to a general warm-up or as a recovery strategy after strenuous exercise (Wiewelhove et al., 2019; Hendricks et al., 2020; Skinner et al., 2020). A recent meta-analysis by Wiewelhove et al. (2019) has shown that FR performed before activity may improve flexibility and sprint performance, while not affecting strength or jumping performance. Additionally, FR following intensive exercise seems to ameliorate declines in sprint and strength performance as well as decrease perception of post-exercise induced muscle pain. Based on their findings, the authors concluded that FR could be used in clinical practice as an addition to warm-up in order to improve performance, or after activity to augment the recovery.

Despite a vast amount of research on FR, most of the available studies did not evaluate the effects of adding FR to a general warm-up on hamstring flexibility. Morales-Artacho and colleagues (2017) found that adding FR to a cycling warm-up

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protocol does not result in additional improvements of passive knee extension ROM. Moreover, studies have not observed any additional benefits of FR in comparison to dynamic stretching exercises alone (Sagiroglu et al., 2017; Smith et al., 2018; Richman et al., 2019). On the other hand, Sagiroglu et al. (2017) reported significant short-term improvements after the addition of FR to aerobic running. All things considered, evidence regarding the additional benefits of adding FR to a general warm-up on knee extension or hip flexion ROM appears to be contradictory.

Current research findings indicate that adding FR to a warm-up does not affect maximal knee flexion strength. It is worth noting that the majority of studies have evaluated the effects of FR on isometric (Sullivan et al., 2013; Behara & Jacobson, 2017; Killen et al., 2019) and concentric strength (Su et al., 2017; Lee et al., 2018). Eccentric knee flexor strength seems to be an important factor in injury prevention, as it is often linked to increased risk of sustaining a hamstring strain injury (Green et al., 2020). Additionally, eccentric knee flexor strength has an impact on sports performance. High levels of hamstring strength are associated with superior horizontal force production and consequently enhanced sprint performance (Morin et al., 2015). Therefore, it is desired that the implementation of FR during a warm-up does not have a negative impact on eccentric knee flexor strength.

The available literature lacks studies investigating whether the addition of short bouts of FR to a general warm-up results in further improvements of hamstring flexibility and whether it affects eccentric knee flexion strength. Accordingly, the aim of our study was to evaluate the effect of adding a short bout of FR to an aerobic warm-up on knee flexion concentric and eccentric strength as well as active and passive flexibility of the hamstrings. To the best of our knowledge, no study to date has assessed the effects of FR as an addition to a warm-up on eccentric muscle strength.

Methods

Participants

Fourteen healthy volunteers (7 males, 7 females; age=25.5±4.7 years, height=171.6±9.5 cm, body mass=69.3±13.8 kg, BMI=23.3±2.8, body fat=19.7±4.1) were included in the study. The sample size was calculated using G-power to reach an effect size reported by previous studies (Madoni et al., 2018; Phillips et al., 2021), statistical power of 0.80 and statistical significance of 0.05. Inclusion criteria were age between 20 and 40 years and regular physical activity (>150 min per week) (Bull et al., 2020). Participants were excluded if they reported trunk or lower extremity injuries in the past 12 months, participated regularly in sports training or had any serious systemic disease. The study was conducted according to the Helsinki declaration and was approved by the Slovenian National Ethics Committee (0120-557/2017/4).

Study design

This study was a within-subject randomized controlled trial in which one leg served as the control and the other as the intervention leg. The dominant (e.g. the leg participants kick the ball with) and non-dominant legs were randomized into the intervention and control groups, and order of measurement was also randomized, in a counterbalanced manner using the Latin square method. Prior to the beginning of measurement, the participants were informed about the study purpose and possible risks of participation. Baseline measurements included the passive straight leg raise test (PSLRT) and the active knee extension test (AKET). Afterwards, the participants engaged in an aerobic warm-up which consisted of 10 minutes of cycling at an individualized intensity (1.5 W per kg of body mass) at a standardized cadence of 90 bpm. Subsequently, the intervention leg was exposed to the FR protocol. The final measurements comprised PSLRT and AKET along with the isokinetic maximal knee flexion strength assessment. Strength assessment was performed only following the intervention, to eliminate the possible effects of maximal eccentric exertion during strength testing. The researcher that performed the measurements was blinded to the assignment of the legs to experimental and control groups.

Hamstring flexibility

Passive and active hamstring flexibility were evaluated using the passive straight leg raise test (PSLRT) and the active knee extension test (AKET), respectively. The ROM was determined with a digital inclinometer (Baseline Digital Inclinometer, Fabrication Enterprises, White Plains, USA). For both measurements the inclinometer was placed on the middle of the tibia (half distance between the medial joint line of the knee and medial malleoli). For the PSLRT, the participants lay supine on a therapeutic table. They were instructed to fully relax. The first researcher stabilized the evaluated knee in full extension and performed passive hip flexion, while stabilizing the non-evaluated thigh. The second researcher palpated under the lumbosacral region to determine at which point the pelvis started to excessively tilt posteriorly (Clarkson & Gilewich, 1989). This point was defined as the end of ROM. For AKET, the participants lay supine on a training mat. The first researcher stabilized the evaluated hip in 90° of hip flexion. The opposite leg was fixated on the table. The participants were asked to actively extend their knee as much as possible. The second researcher measured the ROM with an inclinometer. Two repetitions were performed for each leg. The average value of the two repetitions was taken into further analysis.

Knee flexion strength

Maximal knee flexion strength was measured using an isokinetic dynamometer (Humac Norm, Computer Sports Medicine Inc, Massachusetts, USA). The participants sat on the dynamometer with their hips flexed at 85° and positioned in neutral in the frontal and transverse plane. The dynamometer's axis was aligned with the lateral femoral condyle. Strap belts were used to fixate the measured thigh and trunk. The length of the lever bar was adjusted individually. The distal support was placed just proximal to the ankle joint, so that ankle motion was not compromised. After the participants were positioned, a familiarization trial was introduced (one set of five repetitions). Afterwards, two sets of five repetitions of eccentric-concentric cycles at 60 °/s were performed on each leg. The sets were interspersed with 2 min of rest. The participants were instructed to pull with their shin towards their buttock as hard as they could. Throughout the exertion, the researchers verbally encouraged the participants to assure their maximal engagement. Peak and average torque (Nm) values for both contraction modes were taken into analysis. Peak torque was defined as the highest value at constant speed. Average torque was defined as the average of three repetitions of the more successful set.

Foam rolling

The intervention leg was exposed to a short bout of FR. We used a rigid foam roller with a smooth surface. The FR consisted of two sets of one minute, with one minute of rest in between. A phone metronome application was used to control the tempo, which was set at 27 beats per minute. The participants were instructed to put as much weight as possible on the intervention leg during FR. To increase the pressure, the control leg was crossed and placed over the intervention leg (Figure 1). FR was applied from the ischial tuberosity to the popliteal fossa.

FIGURE 1. Foam rolling of the posterior thigh. To ensure a standardized range the participants were placed between a wall and a pad, which limited further motion of the foam roller.

Statistical analysis

The acquired data were statistically analysed in SPSS (version 25.0, SPSS Inc., Chicago, United States). The normality of distribution was verified using the Shapiro-Wilko test, coefficients of skewness and kurtosis. In case of non-normal distribution, the data were logarithmically transformed. For peak and average knee flexion torque, the two legs were compared using a paired samples t-test. For active and passive ROM, an analysis of variance for the two groups was performed to analyse the interaction effect between time and group. Statistical significance was set at α=0.05. The effect sizes were expressed as partial eta squared (η^2) and interpreted as small (<0.13), medium (0.13–0.26), and large (>0.26; Bakeman, 2005). The effect sizes for t-tests were calculated as Cohen's d (0.0–0.2 – trivial; 0.2–0.6 – moderate; 0.6–1.2 – large; >1.2 – very large; Bernards et al., 2017).

Results

We did not find a significant time × group interaction (p=0.82; η^2=0.002) or group effect (p=0.89, η^2=0.001) for passive ROM. The effect of time was large and statistically significant (p<0.001, η^2=0.51).

Likewise, we did not find a significant time × group interaction (p=0.94, η^2<0.001) or group effect (p=0.943; η^2<0.001) for active ROM. The effect of time was marginally significant (p=0.05, η^2=0.14). Figure 2 represents average changes of ROM.

No significant differences were observed between the control and intervention leg, neither for the peak knee flexor concentric (t=-1.57, p=0.14, d=0.42) and eccentric torque (t=-1.96, p=0.07, d=0.52), nor for the average knee flexor concentric (t=1.35, p=0.20, d=0.36) and eccentric torque (t=-0.58, p=0.58, d=0.15). Figure 3 represents the average values for peak and average knee flexion strength.

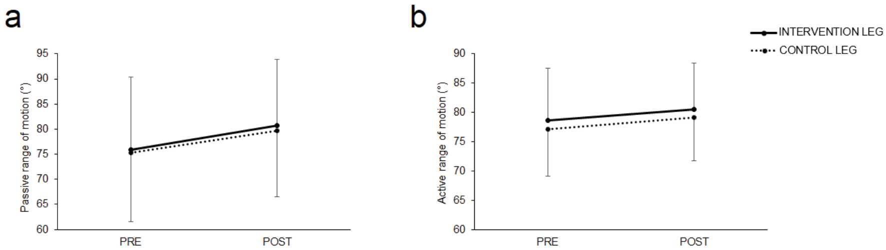

FIGURE 2. Passive (a) and active (b) hamstring flexibility measured on intervention and control leg before (PRE) and after (POST) intervention.

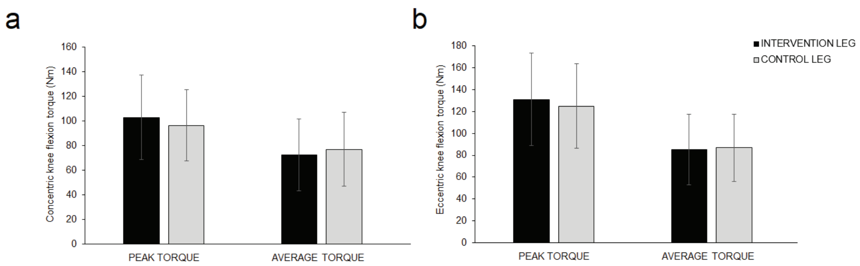

FIGURE 3. Comparison of knee flexion peak and average torque measured during concentric (a) and eccentric (b) exertion of the intervention and control leg.

Discussion

The aim of the present study was to evaluate whether the addition of a short bout of FR to an aerobic warm-up has additional benefits on hamstring flexibility and whether it has an impact on strength. Our results indicate that 2 min FR of the hamstring muscles, as an addition to an aerobic warm-up, does not result in further improvements (compared to warm-up alone) of hamstring flexibility. Importantly, we found that adding FR does not have a negative effect on concentric or eccentric knee flexion strength. Additionally, the time effect was significant for the PSLRT and marginally significant for the AKET, which shows that the warm-up had a positive effect on hamstring flexibility.

Our results are comparable to the findings of Morales-Artacho et al. (2017), who performed the passive knee extension test. Although their aerobic warm-up protocol was of higher intensity and their FR protocol was of longer duration, they found no additional benefit of FR. Also, Couture and colleagues (2015) did not observe any difference regarding the passive knee extension test when adding FR to an aerobic warm-up, regardless of the duration of FR. In contrast, Behara and Jacobson (2017) found that the addition of FR to an aerobic warm-up resulted in improvement of the PSLRT, but not when compared to dynamic stretching. Furthermore, the studies that evaluated the influence of adding FR to dynamic stretching on the sit and reach test reported similar findings to ours (Peacock et al., 2014; Smith et al., 2018). On the other hand, Sagiroglu et al. (2017) found an immediate improvement in the sit and reach test after adding FR to an aerobic warm-up. However, their aerobic warm-up was rather short (5 minutes) and a substantial amount of time elapsed before the post-intervention measurements. Richman et al. (2019) observed that the addition of FR, but not walking, to an aerobic warm-up resulted in significant improvements in the sit and reach distance. After adding dynamic stretching exercises, there were no significant differences between groups. It is worth noting that in both studies that found improvements of flexibility after adding FR to an aerobic warm-up, the warm-up was performed preceding baseline measurements (Behara & Jacobson, 2017; Sagiroglu et al., 2017). Additionally, Behara and Jacobson (2017) did not report a comparison with a control group. Thus, one cannot safely assume that adding FR further improved ROM. Furthermore, the sit and reach test does not assess exclusively hip ROM and is thus not the most appropriate test for evaluating hamstring flexibility.

In the present study, hamstring flexibility increased following an aerobic warm-up regardless of whether FR was added, which is indicated by a significant time effect. An improvement of hamstring flexibility following an aerobic warm-up was reported previously by Morales-Artacho et al. (2017) and O'Sullivan et al. (2009). Increased ROM following aerobic activities is likely related to increased tissue temperature (Gleeson, 1998). Higher tissue temperature decreases its viscoelasticity and alters its mechanical properties, possibly leading to decreased tissue stiffness. Indeed, McNair (1996) found that plantar flexor stiffness decreased following 10 minutes of running. However, the authors did not observe a difference in dorsiflexion ROM. Also, decreased tissue stiffness is frequently mentioned as a possible effect of FR. This is in accordance with Morales-Artacho et al. (2017), who reported decreased passive stiffness of the hamstrings and decreased passive resistive knee flexion torque following cycling and FR. However, when only FR was implemented, the reduction in passive stiffness was not accompanied by improvements in passive ROM. More research is needed to establish the possible mechanisms underpinning the improvements of flexibility following warm-up.

Our results indicate that FR prior to activity does not lead to reductions in concentric and eccentric knee flexion strength. This is in agreement with the previous studies that measured isometric (Sullivan et al., 2013; Behara & Jacobson, 2017) and concentric knee flexion strength (Su et al., 2017; Lee et al., 2018), although the FR protocols implemented in the related studies differ in duration and tempo. To our knowledge, the present study is the first to evaluate the effects of FR on eccentric knee flexion torque. We hypothesized that adding FR to a warm-up will not affect eccentric knee flexion peak torque. Surprisingly, there was a trend of higher eccentric strength in our study that was marginally statistically insignificant. This could explain the improved sprint performance shown following FR (Wiewelhove et al., 2019), as eccentric knee flexor torque is related to sprint performance (Morin et al., 2015). Thus, short bouts of FR of the hamstrings might not have a negative impact on horizontal force production and hamstring injury risk, but this assumption would need to be tested directly. If this is indeed the case, a short bout of FR could be incorporated as part of a warm-up when performing with maximal velocities. Further studies are therefore needed to study the effect of FR on athletic performance and injury risk.

In summary, it appears that adding a short bout of FR to an aerobic warm-up does not have additional benefits on hamstring flexibility. Although the latest meta-analysis reported significant short-term effects of FR on flexibility (Wiewelhove et al., 2019), the majority of the included studies did not compare its effectiveness with a warm-up only control group. Additionally, FR does not have a negative impact on concentric and eccentric knee flexion strength. Furthermore, a potential positive effect on eccentric knee flexion peak torque was observed. Based on the findings of the present and previous studies, we suggest that a short bout of FR is included as part of a comprehensive warm-up solely based on individual preference. FR should not replace the general warm-up.

Finally, several limitations of our study should be considered. The study sample comprised physically active individuals, therefore caution should be taken when generalizing the results to an athletic population. Additionally, hamstring flexibility assessment was performed 5 minutes following the intervention, which could partially explain the absence of effects. Rest was introduced to mimic the practical application in clinical settings, since FR is rarely performed directly before activity. Strength assessments were not performed before the intervention to avoid the possible effects of maximal eccentric exertion during strength testing.

Conclusions

The main findings of this within-subject randomized controlled study are that adding a short bout of FR to an aerobic warm-up does not have additional benefits on hamstring flexibility and does not affect maximal knee flexion strength. Moreover, it seems that adding FR could have a positive impact on eccentric knee flexion maximal strength. Based on our findings, we recommend that a short bout of FR should be included in a warm-up solely based on individual preference.

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Conflict of Interest
The author declares that there is no conflict of interest.

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