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The foam roll as a tool to improve hamstring flexibility

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Short title: Foam rolling improves hamstring flexibility

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Abstract

Although foam rolling is a common myofascial therapy used to increase range of motion (ROM), research is limited on the effectiveness of foam rolling on soft tissue extensibility. The aim of this study was to determine the **effect of a four week training period of the foam** roll method on hamstring flexibility. Furthermore, the study was designed to compare the effectiveness of the foam roll **myofascial release** with a conventional contract-relax PNF stretching method and a control group. Forty healthy males (age: 17-47 yrs) were randomly assigned to a Foam Roll group (FOAM, *n* = 13), a Contract-Relax PNF stretching group (CRPNF, *n* = 14), or a Control Group (CG, *n* = 13). The FOAM group massaged their hamstring muscles with the foam roll three times per week for four weeks (12 training sessions). The CRPNF group was assigned to 12 sessions of contract-relax PNF stretching. The CG under-went no intervention. Hamstring flexibility (ROM) was measured by a stand-and-reach test before and after the intervention period. Two way repeated measures ANOVA showed a significant global time effect ($P<0.001$) and an interaction effect for time x treatment ($P=0.004$) demonstrating greater improvements in FOAM and CRPNF compared with CG, but no difference between the former. Delta changes from baseline to post intervention in ROM were not related to baseline ROM. The foam roll can be seen as an effective tool to increase hamstring flexibility within four weeks. The effects are comparable with the scientifically proven contract-relax PNF stretching method.

Key words: contract-relax PNF; myofascial release; range of motion; stretching

INTRODUCTION

Flexibility is an important part of motor abilities with human movement depending on the degree of range of motion (ROM) available in synovial joints (19). Furthermore, flexibility is important in both the prevention and the rehabilitation of musculoskeletal injuries (24). ROM is determined by joint **structure**, congruency, capsuloligamentous structures and muscles. Muscle tension is composed of active and passive tension with the former defined by alpha- and gamma innervation (neuromuscular properties of muscle) and the latter by viscoelasticity and the fascia **(19)**. Muscle tightness is one of many reasons for reduced joint ROM. It is the result of an increase in active or passive tension. While active tension shortens the muscle through spasm or contraction, passive tension is caused by postural adaptation or scarring. As a consequence ROM **abnormalities** may create a muscle imbalance (19).

Shortness and/or tightness of hamstring muscles are risk factors for back pain **(11, 16, 21).** In this context, Brodersen, Pedersen and Reimers (2) demonstrated that short hamstrings were fairly common in Danish **students** over the age of ten, and with that, the incidence of back pain rose significantly, reaching 15% in students with short hamstring muscles. In addition, people with short hamstring muscles also tend to offset with an increased lumbar flexion during bending forward, sitting down or reaching the toes (21). It also was shown that people with patellofemoral pain had significantly shorter hamstring muscles than asymptomatic controls (31). Witvrouw, Danneels, Asselman, D'Have and Cambier (32) reported in a prospective study that soccer players with reduced hamstring flexibility were more likely to develop hamstring injuries.

There are different methods or techniques for improving the length of a musculotendinous unit. The classical stretching methods, more precisely, static (active, passive), dynamic (active, ballistic) and pre-contraction (Proprioceptive Neuromuscular Facilitation stretching PNF, Post-Isometric Relaxation PIR) stretches (19); or myofascial techniques such as Myofascial Release or Rolfing can be applied .

One technique known as self-myofascial release is foam rolling. The foam roll is a solid foam cylinder available in different degrees of hardness and size. The exerted pressure of the foam roll stimulates the Golgi Tendon Unit and decreases muscle tension (12). **Another possible** effect is improved hydration of tissues. While working, soft tissue is squeezed like a sponge; consequently, it is soaked through with fluid, which improves motion between the different layers of fascia, as well as increases blood flow and temperature (23). It is hypothesized that foam rolling releases fascial adhesions and reduces scar tissue **(12)**. For this reason, it is possible to prevent chronic myofascial pain syndrome and dysfunctional posture. In addition, the foam roll reduces regeneration time and improves muscle performance (12).

From a scientific perspective, it is important to mention that many **effects** are assumed, even though they are not yet proven. All studies, except one, on foam rolling addresses acute effects. MacDonald, Penney, Mullaley, Cuconato, Drake, Behm and Button (13) demonstrated that an acute bout of foam rolling on the quadriceps muscles increases knee joint ROM. Similarly, a stick roller massage (similar principle to foam roll) resulted in an acute increase of hamstring flexibility (26). The study of Miller and Rockey (15) is the only study that investigated chronic effects of foam rolling. They reported a significant improvement of hamstring flexibility after eight weeks in the foam roll group, as well as in the control **group, possibly based on uncontrolled testing time during the day, exclusive inclusion of partici-**

pants with tight hamstrings, and improvements in ROM for female participants only, however with no control of gender effects. It is worth noting here that the effectiveness of foam rolling on flexibility had not yet been compared with classical stretching methods.

In the past, many studies concerning the effect of different stretching techniques on hamstring flexibility were performed. The evidence appears to indicate that a variety of stretching techniques, positions and durations increase ROM (5). The contract-relax PNF (CRPNF) method is a dynamic technique whereby a small amount of motion is tolerated. In comparison with static stretching, pre-contracting stretching yields greater acute gains in ROM (19, 25) and at a faster rate than static stretching (27). Furthermore, it is seen to be more functional because it improves active and passive flexibility (25). The aim of this study was to investigate the training effect of the foam roll on flexibility of hamstring muscles and to compare it with CRPNF stretching. The specific hypotheses were 1) that foam rolling increases flexibility of hamstring muscles, and 2) that foam rolling provides greater increases in hamstring muscle flexibility compared with CRPNF stretching.

METHODS

Experimental Approach to the Problem

A randomized, controlled clinical trial using a pre/post-test design was used. All participants completed a hamstring flexibility test consisting of a stand-and-reach test, after which they were randomly assigned to two intervention groups, the Foam Roll Group (FOAM, n = 13) and the Contract-Relax PNF Stretching Group (CRPNF, n = 14), and a Control Group (CG, n = 13). No differences in anthropometric and age related parameters were found between the three groups at baseline (Table 1)**.** Subsequently, the intervention groups were instructed about the foam roll and the contract-relax PNF stretching exercises. In addition, a training protocol was handed out in which participants were asked to document each training session. Following a four week intervention period, the stand-and-reach test for each group was executed again.

Subjects

Forty seven recreationally active male participants performing 2-3 times/week sport activity (mean ± SD, age: 31.3 ± 9.2; weight: 78.0 ± 9.9; height 181.4 ± 7.0; Body Mass Index [BMI]: 24.3 ± 2.4) were recruited and tested. **Exclusion criteria included recent injury associated with a more than one week pause in performing sport**. **Participants who attended at least 75% of the training sessions were admitted to post-tests**. Training documentation revealed that participants trained in both FOAM and CRPNF 12±1 times (range 10-15 times). **Seven participants did not fulfill the criteria of 75% of the training sessions (4 participants) or did not complete the post-tests (3 participants). All participants had no previous experi-**

ence using a foam roll. The study was approved by the Institutional Review Board and participants were informed in detail about the testing and training procedures, as well as possible benefits and risks of the investigation prior to signing an institutionally approved informed consent to participate in the study.

***** Table 1, approximately here *****

Intervention

The intervention period consisted of three training sessions per week for four weeks. This duration was based on findings of Chan, Hong and Robinson (4) demonstrating that both a four week and an eight week static stretching period improved hamstring flexibility, but with no difference between groups.

The FOAM group was instructed to train their hamstring flexibility with the foam roll in a supine position. They were briefed to use the foam roll **with a pressure** on their pain threshold. In each subset, they rolled their hamstrings unilaterally for 30-40 s (ten times back and forth). After the first leg was finished, they repeated the exercise with the other leg (= one set). Altogether, three sets in one session were performed. The protocol of foam rolling was based on the recommendations of Lukas (12), which represent practical recommendations known from clinical experience.

The CRPNF group used the contract-relax PNF stretching method. Based on the study of Feland and Marin (7), participants performed three separate CRPNF stretches at approximately 25% of their maximal voluntary isometric contraction with each leg. Participants were instructed to lie in a supine position. Next, they stretched their leg using a rope or a towel until an uncomfortable stretching sensation was felt. In this position, a contraction of the hamstring muscles against the rope or towel was carried out. After six seconds of contraction, they relaxed the muscles while keeping the leg position, and then stretched on to the next barrier within 10 seconds. This was repeated three times to equal one set and a total of three sets were performed. The right and left legs were stretched alternately. The CG performed only the pre- and post-tests and were advised to maintain their usual training routine. **As mentioned above, all the participants were recreationally active and performed in addition to the experimental treatment 2-3 times/week sport activities as soccer and cycling.**

Stand-and-reach Test

The flexibility of hamstring muscles was measured by using the stand-and-reach test. It is a common test for measuring flexibility of the hamstrings and the lower back. Reliability ($r = 0.88$-0.98) and objectivity of the stand-and-reach test ($r = 0.95$-0.98) meet the required scientific quality criteria (8).

Prior to testing, subjects performed 5-10 minutes of light jogging as a general warm-up. After warm-up the stand-and-reach test was demonstrated by the instructor. Participants stood on a wooden box without shoes, feet together, with legs extended and toes touching the test panel. Participants were then asked to bend forward as far as possible touching the test panel with their fingers, holding the reached position for two seconds. The distance from the panel was recorded from a vertical scale in half centimeters. Data above the toe line (zero line) were noted with a minus and data below with a plus. Two measurements for each participant were taken and the mean was used for further analysis. Both pre-test and post-test measurements took place indoors at a standardized room temperature after 5 p.m.

Statistical Analyses

Normal distribution was determined by the Shapiro Wilk Test. A two way repeated measures ANOVA (time x treatment) was performed to determine treatment, time and interaction (time x treatment) effects. In the event an interaction effect occurred, a one way ANOVA over the delta values between pre- and post-test was performed. In case of a main effect for time, paired sample t-tests for post hoc comparisons were applied. The level of significance was set at alpha < 0.05. Data were reported as means ± standard deviation. All data were analyzed using SPSS 23.0 (SPSS Inc, Chicago, IL, USA).

RESULTS

Baseline and post intervention values for FOAM, CRPNF and CG are presented in Table 2. Statistical analysis revealed a main effect for time ($P < 0.001$) with no main effect for group ($P = 0.123$). An interaction effect for time x treatment ($P = 0.004$) was found, demonstrating that greater improvements in CRPNF and FOAM were achieved compared with CG ($P = 0.004$ and $P = 0.033$), while no differences were found between the two intervention groups ($P = 0.60$). Within groups, FOAM increased ROM by 3.0 ± 2.1 cm ($P = 0.001$), CRPNF by 4.0 ± 2.9 cm ($P = 0.003$), and no change in CG (0.4 ± 1.7 cm, $P = 0.46$). No significant correlations between baseline ROM and the delta changes within each training group, or for the pooled data of both training groups were found. The delta changes from baseline to post intervention measurements are presented in Figure 1.

DISCUSSION

The aim of the current study was to determine the training effect of a foam roll massage on flexibility of hamstring muscles compared with a contract-relax PNF method and a control group. The training period of four weeks with three training sessions per week improved ROM in the stand-and-reach test, that is, hamstring flexibility, in both the FOAM and CRPNF group, while no changes occurred in the CG.

To the best of our knowledge, the study of Miller and Rockey (15) is the only one that analyzed chronic training effects of FOAM rolling. They demonstrated that an eight week training intervention with three sessions per week led to a significant increase in ROM in both the foam roll group and in the control group. These results differ somewhat from those of our study where improvements in hamstring flexibility were found only in the FOAM and CRPNF groups, with no changes in the CG. Ways in which the study of Miller and Rockey (15) differed from the current study were: 1) the participation of both male and female subjects; 2) different testing setup with active knee extension in supine position for the dominant and non-dominant leg was determined using an inclinometer; 3) tight hamstrings with less than 80° of knee extension ROM as an inclusion criteria; and 4) uncontrolled testing time during the day. On closer examination of the results, it is apparent that in the control group, female participants in particular improved their ROM; however, within the statistical analysis, no controls for gender effects were presented. In the current study, only male participants with and without tight hamstring muscles were included, and the statistical analysis revealed that baseline ROM was not related to delta changes from baseline to post intervention measurements. Therefore, training induced changes in hamstring flexibility were not related to tight or non-tight hamstrings. Furthermore, it was demonstrated that flexibility is dependent on the time of day testing occurs (9, 10); therefore, standardization of testing time during the day—for both baseline and post intervention testing—seems to be a relevant detail.

The chronical improvements in hamstring flexibility in the current study are comparable with studies about acute effects of the foam roll or comparable tools. In a study by MacDonald, Penney, Mullaley, Cuconato, Drake, Behm and Button (13), the acute effect of two one-minute bouts of self-myofascial release with the foam roll (range of hip extension with knee flexed) was found to significantly increase quadricep flexibility two minutes (10°) and 10 minutes (8°) following foam rolling. Comparable findings were demonstrated by Sullivan, Silvey, Button and Behm (26) where instead of a foam roll, a stick roller massager was used. They observed an acute increase of 4.3 % in the sit-and-reach test after using the roller massager for either 10 or 5 s. However, in the current study, the last training session was, at the latest, one day prior to post-intervention; therefore, these changes can be regarded as training induced and not acute effects.

Several mechanisms might lie behind the improvement in hamstring flexibility by foam rolling in the current study. The fascia mainly consists of collagen fibers (as well as, to a lesser degree, elastic and reticular fibers), fibroblasts and water-binding ground substance (22). As a natural consequence of trauma, inflammation or immobility, the fascia loses flexibility and becomes restricted. According to Pischinger´s ground regulation system, the phase state of the connective tissue solidifies and develops adhesions **(1).** The aim of myofascial release methods is to rehydrate the fascia and in this way create a fluid gel-like extracellular environment to provide a greater increase in ROM (1, 23), called the thixotropic property of fascia (22). Okamoto, Masuhara and Ikuta (18) reported that self-myofascial release with the foam roll led to an acute reduced arterial stiffness and an improved endothelial vascular function. Therefore, the encouragement of blood flow is seen as another purpose of myofascial release with the foam roll because arterial distensibility is associated with flexibility. These mechanisms are likely to explain the effects of foam rolling in the current study; however, long term training effects were not analyzed.

As mentioned earlier, two key aspects of the loss of flexibility are fascial restriction and adhesion. As a consequence, stiffness accrues, which in turn leads to not only local, but also overall problems in the body with acute and chronic dysbalance (myofascial imbalance, joint dysfunction, pain, and dysfunction in venous and lymphatic systems). It is assumed that self-myofascial release with the foam roll remedies these consequences (12). In this context, Pohl (20) explored a significant difference of the collagen matrix before and after a skin rolling treatment. In his opinion, this is caused by changes in the mechanical forces of fibroblasts and increased microcirculation. Carano and Siciliani (3) found out that cyclical forces stimulate the production of collagenase—an enzyme responsible for remodeling the extracellular matrix—by the fibroblast. Therefore, based on the results of the current study, it might be speculated that there is a positive long term effect of foam rolling on fascial restriction and adhesion.

The results revealed a significant difference in improvement of ROM between the FOAM group and the CG, as well as for the CRPNF group and the CG. No differences occurred between the two intervention groups. Pre-contraction stretching is a common and very effective method to increase ROM (7, 19, 24, 25). The increase in ROM due to pre-contraction stretching is also attributed to a possible neurologic phenomenon (14), while the specific mechanism of action still remains unclear. Most signs point to an increased tolerance to stretching, and not to increased muscle length. The perception of sensation is changed and allows a greater ROM (17, 25, 30). The improvement of ROM in the FOAM group was similar to the CRPNF group. There are many mechanoreceptors in fascia; these are sensory endings that are responsive to compressive and tensile loading. It is claimed that the stimulation of Golgi receptors are essential in myofascial release with the foam roll. The stimulation of Golgi receptors inhibits the muscle spindle activity and decreases muscular tension. This phenomenon is known as autogenic inhibition (12, 28). Fama and Bueti (6) suggested that it is likely that the pressure of the foam roll causes stimulation of the Golgi receptors via ischemic compression. They demonstrated that there was a negative effect of a warm-up with foam rolling on jump performance, especially for the countermovement jump, when compared to a dynamic warm-up. Nevertheless, the stimulation of Golgi receptors only explains the immediate effects of foam rolling and not the observed effects as in the current study. Ruffini receptors and free nerve endings react on sustaining and alternating pressure. On the contrary, Pacini receptors are only responsive to varying pressure (22) and are essential for proprioception, a requirement for proper movement. In fascial training, a proprioceptive refinement is encouraged (23). In the current study, no precise declaration for pressure was given. Participants were advised to train with a melting pressure on their pain threshold. Therefore, it is likely that the pressure varied during training, and as a consequence the application of the foam roll might have stimulated these receptors.

Both hamstring flexibility and lower back flexibility influence the stand-and-reach test. However, in the present study only hamstring muscles were considered. During myofascial release therapy, not only isolated muscles, but also muscle chains should be treated. It is also known that there is only one connected fascia and not different fasciae (1). Therefore, if the whole posterior chain was treated by foam rolling the changes might have been even more pronounced. Additionally, the treatment protocols did not include trigger points, even though the existence of trigger points has a negative influence on myofascial function. A passive technique to release trigger points is to use compression. It is likely that the compression exerted by the foam roll is suitable to release trigger points. However, this treatment of trigger points with the foam roll would have required a subjective and varying time treatment protocol (6, 29).

PRACTICAL APPLICATIONS

The current study demonstrates that foam rolling can be applied as an effective technique for increasing hamstring flexibility within a four week training period. The improvements were similar to the CRPNF method, which is known to be one of the most effective stretching methods to increase ROM. For both techniques, three training sessions per week consisting of three repetitions of 30-40 s (FOAM), or 50 s (CRPNF) were sufficient to improve ROM. In addition, with foam rolling there is a massage effect that does not occur with CRPNF stretching. However, the exact mechanisms of foam rolling still remain unclear and future studies are needed to investigate this issue further.

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Figure 1: Delta changes (mean ± SD) in Stand-and-Reach performance from baseline to post intervention measurements). $^{**}P < 0.01$, $^{***}P < 0.001$, significantly different between the groups; $^{\dagger\dagger}P < 0.01$, $^{\dagger\dagger\dagger}P < 0.001$, significantly different to baseline levels within the group.

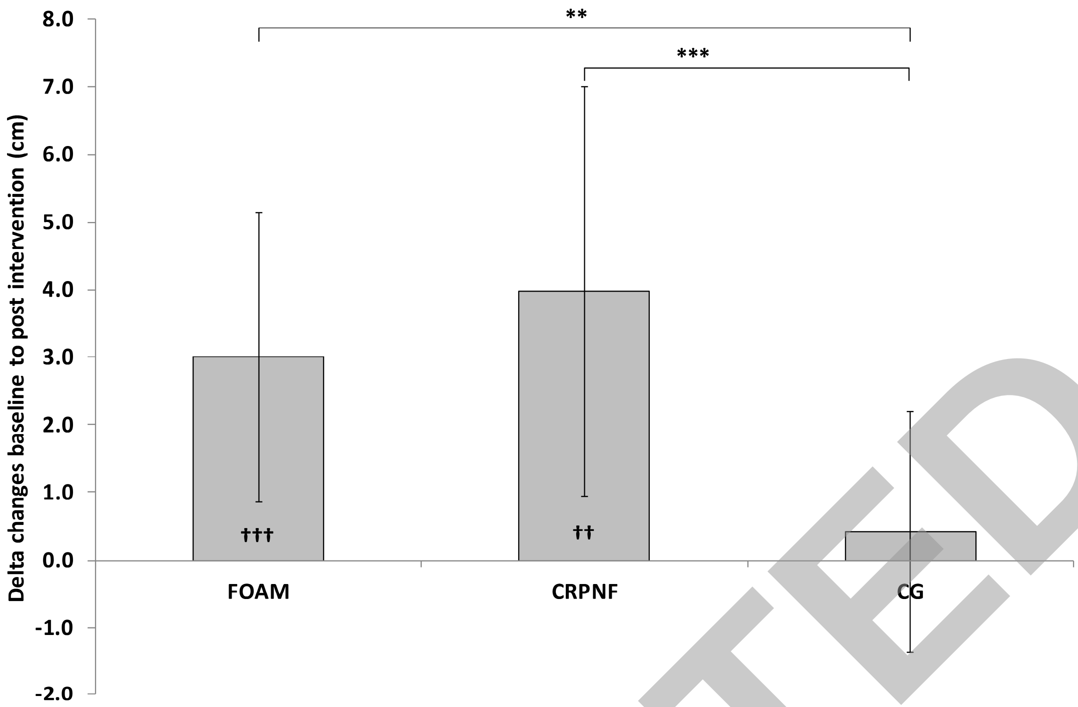
Table 1: Participants characteristics at baseline testing (mean ± SD)

	Training Sessions	Height [m]	Weight [kg]	BMI [kg/m²]	Age [y]
FOAM	12.1 ± 1.1	1.82 ± 0.05	78.0 ± 10.3	23.6 ± 2.7	31.0 ± 8.5
CPNF	12.1 ± 1.1	1.83 ± 0.10	81.0 ± 12.0	24.2 ± 2.0	33.0 ± 10.5
CG	-	1.81 ± 0.05	82.5 ± 7.5	25.1 ± 2.1	30.0 ± 9.0

Table 2: Stand and reach values at baseline and post intervention (mean ± SD)

Group	Baseline [cm]	Post-Intervention [cm]		*F*-Value	*P*-Value	Effect Size $_p\eta^2$	Test Power
FOAM	-3.9 ± 8.0	-0.9 ± 8.7***	Time	$F_{1,30}=36$	< 0.001	0.55	1.0
CRPNF	2.9 ± 10.3	6.8 ± 9.7**	Group	$F_{1,30}=2.2$	0.123	0.13	
CG	-2.9 ± 8.2	-2.5 ± 8.2	Time x Group	$F_{2,30}=6.6$	0.004	0.31	0.88

The values presented are means ± SD. *F* and *P* values were obtained by two-way ANOVA (2 times x 3 groups) with repeated measures. FOAM, foam roll training group; CRPNF, contract-relax PNF stretching group; CG, control group; ** $P < 0.01$; *** $P < 0.001$ significant difference within groups from baseline- to post intervention.



Delta changes baseline to post intervention (cm)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
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†††
††
FOAM
CRPNF
CG