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ORIGINAL RESEARCH

COMPARISON OF THREE DIFFERENT DENSITY TYPE FOAM ROLLERS ON KNEE RANGE OF MOTION AND PRESSURE PAIN THRESHOLD: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Foam rolling is a popular form of roller massage. To date, no studies have examined the therapeutic effects of different density type rollers. Understanding the different densities may provide clinicians with the knowledge to accurately prescribe a particular foam roller and safely progress the client.

Purpose: The purpose of this study was to compare the immediate effects of three different density type foam rollers on prone passive knee flexion range of motion (ROM) and pressure pain thresholds (PPT) of the quadriceps musculature.

Study Design: Pretest, posttest randomized controlled trial.

Methods: Thirty-six recreationally active adults were randomly allocated to one of three groups: soft density, medium density, and hard density foam roller. The intervention lasted a total of two minutes. Outcome measures included prone passive knee flexion ROM and PPT. Statistical analysis included parametric and non-parametric tests to measure changes among groups.

Results: Between group comparisons revealed no statistically significant differences between all three rollers for knee ROM ($p = .78$) and PPT ($p = .37$). Within group comparison for ROM revealed an 8° ($p < 0.001$) post-intervention increase for the medium and hard density rollers and a 7° ($p < 0.001$) increase for the soft density roller. For PPT, there was a post-intervention increase of 180 kPa ($p < 0.001$) for the medium density roller, 175 kPa ($p < 0.001$) for the soft density roller, and 151 kPa ($p < 0.001$) for the hard density roller.

Conclusion: All three roller densities produced similar post-intervention effects on knee ROM and PPT. These observed changes may be due to a local mechanical and global neurophysiological response from the pressure applied by the roller. The client's pain perception may have an influence on treatment and preference for a specific foam roller. Clinicians may want to consider such factors when prescribing foam rolling as an intervention.

Level of evidence: 2C

Keywords: Massage, muscle soreness, perceived pain, recovery, roller

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Conflict of Interest: The authors have no conflict of interest with this study.

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INTRODUCTION

The popularity and use of foam rolling has increased over the past decade and has emerged as one of the top 20 fitness trends the past two years (2016-2017) in the United States.[1,2] The majority of research has focused on the effects of foam rolling as a form of roller massage.[3] The research suggests that foam rolling may be used as a warm-up without negatively effecting performance and may enhance joint mobility at the shoulder,[4,5] lumbopelvis,[6,7] hip,[8-14] knee,[14-18] and ankle.[19,20] Researchers have found that foam rolling may reduce post exercise decrements in muscle performance,[3,21-24], increase posttreatment pressure pain thresholds (PPT),[15,16,22,24-27] and reduce the effects of delayed onset muscle soreness in healthy individuals.[3,21,28-30] Several recent studies have also documented positive post-exercise effects of rolling for different sports,[29,31-33] occupations,[34] and fibromyalgia.[35]

Many different foam rollers are available to consumers which vary in density, shape, and surface texture. These architectural differences may influence how the myofascial tissues are being massaged during treatment. More specifically, the density and surface texture of the foam roller may provide a more effective massage to the tissue than a less dense roller. Curran et al[36] investigated the pressure being applied by a higher density, multilevel textured surface foam roller and a lower density, solid EVA roller with a uniform textured surface to the lateral thigh of ten subjects (N = 10). The researchers found that the higher density, multilevel textured roller produced more pressure and isolated contact area on the target tissues than the less dense, smooth textured roller.[36] Despite the small sample size, this study has become a reference standard and has prompted researchers to use higher density foam rollers in their investigations.[3,15,21,28,37]

Since the Curran et al[36] study, no other investigators have compared the therapeutic effects of different density rollers. They have either used commercial high-density rollers or developed their own custom high-density roller.[3,21,28] The unknown therapeutic effects of various density rollers create a knowledge gap that has potential implications for clinical practice. The clinician is challenged with the inability to provide an evidence based recommendation for the type of foam roller for a patient and may depend on personal preference.[3] Furthermore, the client may purchase a foam roller based upon price, personal preference, or recommendation by a clinician.

Further investigation into the therapeutic effects of different density foam rollers is warranted given the gap in the knowledge about foam rolling. Understanding the effects of different density foam rollers may provide clinicians with the knowledge to more accurately prescribe a particular foam roll and to safely progress the client through different densities. The purpose of this study was to compare the immediate effects of three different density type rollers on passive knee range of motion (ROM) and pressure pain threshold (PPT). The authors of this study hypothesized that the higher density foam roller will have a greater effect than the less dense roller. This investigation was also considered exploratory and a starting point for future research.

METHODS

This pretest, posttest randomized controlled trial was approved by the Institutional Review Board (IRB:18-023) at California State University Dominguez Hills.

Subjects

Thirty-six recreationally active adults (Males = 26, Females = 10) were recruited via convenience sampling (e.g. flyers) and randomly allocated into three groups of 12 subjects: (1) soft density, (2) medium density, and (3) hard density foam roller intervention groups (Table 1). Recruited subjects reported participated in recreational fitness activities (e.g. walking) and prior experience using a foam roller within the last two years but were not currently using any devices. Exclusion criteria included the presence of any musculoskeletal, systemic, or metabolic disease that would affect lower extremity joint ROM or tolerance to PPT testing and the inability to avoid medications that may affect testing. Descriptive demographic information is provided in Table 2.

Instruments

Two instruments were used in this investigation to measure ROM and PPT. For ROM, the baseline digital inclinometer (Fabrication Enterprises, White Plains, NY, USA) was used to measure passive knee flexion ROM. The manufacturer reports an accuracy

Table 1. *Consort Flow Diagram*

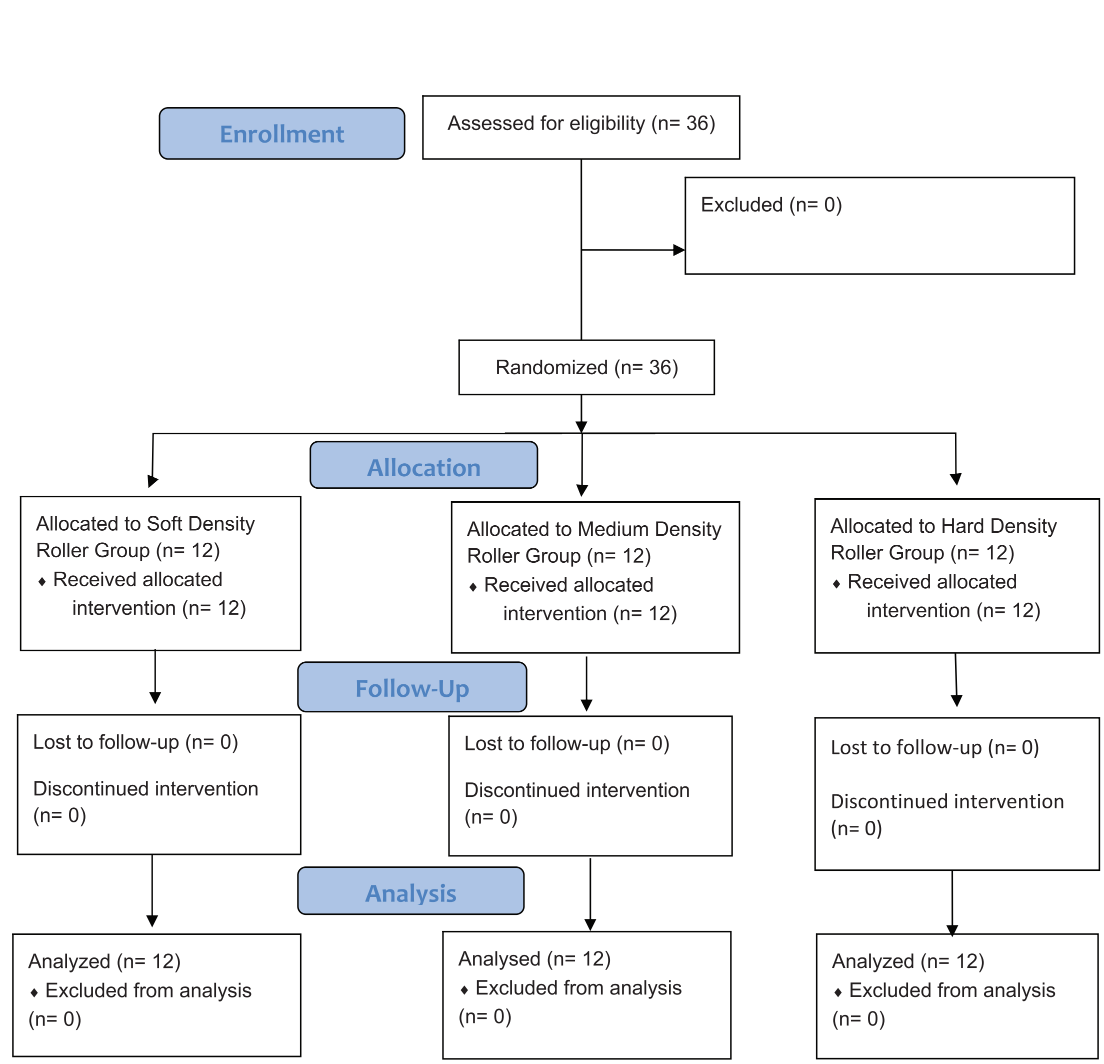

Table 2. *Subject demographics*

Characteristics	Age (years)	Height (cm)	Mass (kg)	BMI (kg/m^2)
Soft Density Roller (N=12)	24.58 ± 3.06 (range 22-27)	170.39 ± 7.14 (range 166-175)	71.14 ± 14.28 (range 62-80)	24.41 ± 3.96 (range 18-31)
Medium Density Roller (N=12)	24.33 ± 1.72 (range 23-25)	172.93 ± 10.13 (range 157-188)	77.47 ± 15.65 (range 51-99)	25.95 ± 3.71 (range 19-31)
Hard Density Roller (N=12)	25.33 ± 5.85 (range 22-29)	169.33 ± 11.73 (range 162-177)	76.73 ± 13.65 (range 68-85)	26.61 ± 2.22 (range 22-30)

Data reported as mean± SD; range (min-max); m=meters; BMI= body mass index; kg/m^2= kilograms-meter squared

of ± 0.5 degrees.[19] This device has been shown to be valid and reliable for measuring lower extremity ROM (Figure 1)[38-41] and has been used in prior foam roller research.[15,26,37] Second, The JTECH (Midvale, UT) Tracker Freedom® wireless algometer (Figure 2) was used with the accompanying Tracker 5® Windows® based software to measure PPT. The manufacturer reports an accuracy error of < ± 0.5% (.05kg/cm^2) for this technology.[42] Algometry is a valid and reliable tool for measuring pressure pain thresholds.[25,43-45] This instrument has also been used in prior foam roller research.[15,26,37]

Figure 1. *Baseline digital inclinometer.*

Figure 2. *JTECH algometer.*

Instructional Video and Foam Rollers

A commercial internet-based instruction video was used in this investigation (TriggerPoint, a division of Implus, LLC, Austin, Texas). The short foam rolling instructional video demonstrated the use of the foam roller on the left quadriceps muscle group. This video has been used in prior foam roll research.[15,26,37] The three foam rollers used in this study were manufactured by TriggerPoint™ and all had the same multilevel GRID surface pattern and diameter (14cm) which allowed for a direct comparison. The difference between the three rollers was the density. The soft density CORE roller (silver) was constructed of solid EVA foam, the medium density GRID roller (orange) had a hard, hollow core that was wrapped in moderately firm EVA foam, and the hard density GRID X roller (black) had a hard, hollow core that was wrapped in very firm EVA foam (Figure 3).

Figure 3. *Soft (silver), medium (orange), and hard (black) foam rollers.*

Outcome Measures

Two outcome measures were used for the pretest and posttest measures for each group. For passive knee flexion ROM, subjects lay prone on a carpeted floor. The examiner grasped the left ankle and passively moved the left knee to the end of the available flexion ROM to the point where the knee could no longer be passively moved without providing overpressure or point of initial discomfort.[15,26,37,46-48] The ROM measurement was then taken by the examiner. The examiner monitored for any compensatory movement through the lower extremity and pelvis. This testing technique was chosen since it replicated the same hip position and knee movements that occurred during the foam roll interventions.[15,26,37] For PPT, the left quadriceps group was tested with the subject in the relaxed standing position (average of two measurements).[16,49,50] The 1.0-cm^2 probe of the algometer was placed into the midline of the left quadriceps (rectus femoris) midway between the iliac crest and superior border of the patella. The graded force was applied at a constant rate of 50-60 kilopascals per second (kPa/sec) until the subject verbaelly reported the presence of pain.[16,49,50] These outcome measures have been used in prior foam roller research.[15,26,37]

Pilot Study

Prior to data collection, a two-session pilot training was conducted to establish intrarater reliability. The primary investigator took all the measurements. The primary investigator is a licensed physical therapist with over 13 years of experience and board certified in orthopaedics. Ten independent subjects were recruited and tested for this portion of the study. The intrarater reliability was calculated using the Intraclass Correlation Coefficient (ICC model 3, 3). There was excellent intrarater reliability for passive knee flexion ROM (ICC = 0.95; 95% CI 0.83-0.99) and pressure algometry (ICC = 0.94; 95% CI 0.61-0.90).[51]

Procedures

All eligible participants were given an IRB approved consent form to read and sign before testing. Participants then completed a questionnaire to provide demographic information. All participants were tested by one investigator and were blinded from the results and other participants enrolled in the study. Testing was conducted between the hours of 10 AM and 2 PM and subjects were instructed to refrain from any strenuous activity for three hours prior to testing and from taking any medication that would interfere with testing. All subjects underwent one session of testing that included: pretest measures, followed by the intervention, then immediate posttest measures.

Prior to testing, the primary investigator first explained the process to each subject and answered any questions. Then each subject was given a foam roller (based on group allocation) and followed an instructional video that demonstrated the use of the foam roll on the left quadriceps muscle group.[15,26,37] Subjects followed the video with no feedback from the observing primary investigator. The instructor in the video provided a brief introduction and then discussed the foam rolling technique. The instructor divided the left quadriceps into *zone one*: top of patella to middle of the quadriceps and *zone two:* middle quadriceps to anterior superior iliac spine. The model in the video was instructed to get in the plank position, position the roller above the left patella and roll back and forth longitudinally in *zone one* four times at a cadence of one inch per second. The model was then instructed to stop at the top of *zone one* followed by four active knee bends to 90 degrees. This sequence was repeated for *zone two*. The intervention portion lasted a total of two minutes. Subjects used the specific foam roll they were assigned to based upon their group allocation (e.g. soft, medium, or hard density). These procedures have been used in prior foam roller research.[15,26,37]

STATISTICAL ANALYSIS

Analysis

Statistical analysis was performed using SPSS version 24.0 (IBM SPSS, Chicago, IL, USA). Subject descriptive data was calculated and reported as the mean and standard deviation (SD) for age, height, body mass, and body mass index (BMI) (Table 2). Group differences were calculated using the ANOVA statistic for continuous level data and the Kruskal Wallis statistic for ordinal level data. Between group difference were calculated using the ANCOVA statistic.[52] For the ANCOVA, the independent variable was the group, dependent variable was post-test scores, and pretest scores was the covariate. Within group comparisons were calculated using the paired *t*-test. Effect size (ES) was calculated ($d = M_1 - M_2 / \sigma_{pooled}$) for each group. Effect size of > .70 was considered strong, .41 to .70 was moderate, and < .40 was weak.[53] All statistical assumptions were met for the ANOVA, ANCOVA and paired *t*-test statistics. Statistical significance was considered $p < .05$ using a conservative two-tailed test.

RESULTS

Thirty-six subjects completed the study (Table 1). There was no statistically significant difference between groups for age (p = .81), height (p = .66), body mass (p = .38), or BMI (p = .27). There were no adverse events or subject attrition during data collection. Patient demographic data is presented in Table 2.

Between Group Analysis

Between group comparisons were calculated. For passive knee flexion ROM, the between group analysis revealed no significant difference between the three types of foam rollers [$F (2,32) = .247$, $p = .78$, partial $\eta 2 = .015$]. For PPT, no significant differences were found between the three types of rollers [$F (2, 32) = 1.02$, $p = .37$, partial $\eta 2 = .196$].

Within Group Comparison

Within group comparison results are presented in Table 3. For passive knee flexion ROM, within group analysis revealed a *posttest* increase of 7° (p < .001, ES: .92) for the soft density roller, 8° degrees

Table 3. *Pretest, posttest descriptive results*

	Pretest	Posttest	Change	P-Value	Effect Size
Soft Density Roller					
Knee ROM (degrees)	131.93 ± 8.36	139.33 ± 8.01	7.40 ± 0.35	<.001	0.92
Pressure Pain Threshold (kPa)	954.17 ± 232.59	1129.17 ± 226.81	175.00 ± 5.78	<.001	0.76
Medium Density Roller					
Knee ROM (degrees)	127.75 ± 10.46	136.00 ± 11.17	8.25 ± 0.71	<.001	0.76
Pressure Pain Threshold (kPa)	1066.67 ± 212.49	1246.67 ± 212.53	180.00 ± 0.04	<.001	0.85
Hard Density Roller					
Knee ROM (degrees)	132.41 ± 6.20	140.58 ± 6.77	8.17 ± 0.57	<.001	1.26
Pressure Pain Threshold (kPa)	959.16 ± 244.92	1110.00 ± 259.22	150.84 ± 14.30	<.001	0.60

Data reported as mean ± SD, kPa= kilopascals; statistical significance considered p<.05; Effect size: $d = M_1 - M_2 / \sigma_{pooled}$

(p < .001, ES: 0.76) for the medium density roller, and an 8° (p < .001, ES: 1.26) increase for the hard density roller. For PPT, a *posttest* increase of 175 kPa (p < .001, ES: 0.76) for the soft density roller, 180 kPa (p < .001, ES: 0.85) increase for the medium density roller, and a 151 kPa (p < .001, ES: 0.60) increase for the hard density roller. All densities of rollers demonstrated comparable changes in ROM and PPT.

DISCUSSION

This investigation compared the effects of three different density type rollers with the same multilevel surface pattern. This allowed for a direct comparison of different foam roll densities which may have clinical implications. The between group analysis revealed that all three density type rollers produced statistically similar post-test increases in passive knee flexion ROM (p = 0.78) and PPT (p = 0.37). Curran et al[36] is the only known investigation to document the effects of two foam rollers with different densities and surface architecture on myofascial tissues. The researchers did not measure the therapeutic effects of the rollers. This current investigation built upon the prior study by measuring the effects of three density type rollers on knee joint ROM and PPT of the quadriceps.

Clinical Implications

The results of this investigation should be considered exploratory and a starting point for future research. The results suggest that the myofascial system may respond to different density foam rollers in a statistically comparable manner as observed by the post-intervention changes in joint ROM and PPT. These observed changes may be due to a mechanical and neurophysiological response.[19,37,54] The direct pressure of the roller may produce a local mechanical and global neurophysiological effect that influences tissue relaxation and pain reduction in the target and surrounding tissues.[25,55,56] *For tissue relaxation,* the local pressure from the roller may affect the viscoelastic properties of myofascia which may be responsible for the changes. Other mechanisms that may be involved include thixotropy (reduced viscosity), myofascial restriction, fluid changes, and cellular responses.[19,54] Researchers have also found that rolling reduces arterial stiffness[57], increases arterial tissue perfusion,[58] and improves vascular endothelial function[57] which are related to tissue relaxation. *For pain reduction,* researchers have postulated that the pressure from the roller may modulate pain through stimulation of cutaneous receptors,[25] mechanoreceptors,[55] afferent central nociceptive pathways (gate theory of pain),[25,59] and descending anti-nociceptive pathways (diffuse noxious inhibitory control).[7,25] Researchers have found that rolling decreases evoked pain[59] and reduces spinal excitability[55] which provides evidence for these theories.

Because the post-intervention changes among all three density rollers were similar, clinicians may want to consider the client's pain perception when prescribing a particular roller. The Curran et al[36] study supports the effectiveness of a harder density roller but did not consider the influence of a client's pain perception. Pain is a very complex multidimensional process involving the central nervous system and other systems of the body.[60,61] Clients may choose a foam roller based upon their pain perception and threshold during rolling. For example, a hard density roller may produce more discomfort during the intervention eliciting a protective muscle guarding response.[62,63] Understanding this may help guide the clinician in prescribing a specific foam roll and progressing them through the different densities.

Limitations

There are specific limitations to the investigation that need to be discussed. First, this investigation tested healthy subjects which limits the generalizability of the results to this population. Second, the three foam rollers used had the same multilevel GRID pattern surface and diameter which allowed for a direct comparison. Other foam rollers with different surface patterns, diameters, and densities may have produced different results. Third, the short-term effects of each foam roll intervention was studied with the left leg only. Fourth, the testing examiner was not blinded to the results of the study which could have led to testing biases. Last, the instructional video used in the intervention only demonstrated one foam rolling technique on the left quadriceps group. Other rolling techniques may have produced different results as well as testing other muscle groups.

Future research

Future studies are needed to validate the results of this study and to develop a consensus on the optimal type of foam roller for specific clients. Furthermore, research should attempt to determine the longer-term effects of different types of foam rollers based upon surface patterns, density, and foam roll material using the similar research methods. The current foam roller research is variable with different methodology which prevents a direct comparison among studies.[3,28]

CONCLUSION

This was the first investigation to measure the short-term effects of different density foam rollers on passive knee flexion ROM and PPT of the quadriceps musculature. All three foam roll densities produced statistically similar post-intervention effects on both ROM and PPT. These observed changes may be due to a mechanical and neurophysiological response that can be triggered by low, moderate, or high-density roller pressure. The density of the roller and client's pain perception may have an influence on treatment and preference for a specific foam roller. Clinicians may want to consider such factors when prescribing foam rolling as a myofascial intervention.

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