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FASCIA SCIENCE AND CLINICAL APPLICATIONS: Comparative Study

# Roller massage: Comparison of three different surface type pattern foam rollers on passive knee range of motion and pain perception

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A B S T R A C T

*Introduction:* Roller massage with a foam roller has become a common intervention. To date, no studies have examined the therapeutic effects of different surface type rollers. The purpose of this study was to measure the therapeutic effects of three different surface type pattern foam rollers with the same density on passive knee joint range of motion (ROM) and pressure pain threshold (PPT) of the quadriceps.
*Methods:* This pre-test, post-test randomized controlled trial was conducted in a university laboratory. Thirty-six participants ($M = 22$, $F = 14$; mean age $= 25.20 \pm 4.44$ years) were randomly assigned to three groups: (1) smooth surface, (2) multilevel surface, and (3) GRID surface. The intervention was a 2-min rolling session. Outcomes included knee ROM and PPT.
*Results:* Between group comparisons revealed a statistically significant post-intervention difference between the three rollers for knee ROM ($p = 0.04$) and PPT ($p < 0.001$). Within group comparison for ROM revealed a 3-degree ($p = 0.015$) increase for the smooth, a 5-degree ($p < 0.001$) increase for the multilevel, and a 6-degree ($p < 0.001$) increase for the GRID surface roller. For PPT, there was an increase of 14 kPa ($p = 0.562$) for the smooth, 179 kPa ($p < 0.001$) for the multilevel, and 182 kPa ($p < 0.001$) for the GRID.
*Conclusion:* The GRID and multilevel surface rollers produced greater immediate post-intervention effects than the smooth roller. The therapeutic effects of the GRID and multilevel rollers may be due to the surface architecture. These rollers may provide a greater deformation of the tissues which creates a local mechanical and global neurophysiological effect.



## 1. Introduction

Roller massage (RM) with a foam roller has become a common intervention for both fitness and allied health professionals in the United States (Cheatham, 2018). This popularity has stimulated a growing body of research that has focused on both the scientific and therapeutic aspects of the intervention. The research suggests that RM may be used as a warm-up without negatively affecting performance and may enhance joint mobility and range of motion (ROM) at the shoulder (Fairall et al., 2017; Le Gal et al., 2017), lumbopelvis (Grieve et al., 2015; Sullivan et al., 2013), hip (Behara and Jacobson, 2017; Bushell et al., 2015; DeBruyne et al., 2017; Mohr et al., 2014; Monteiro et al., 2017a,b; Murray et al., 2016; Vigotsky et al., 2015), knee (Cheatham et al., 2017a,b; Couture et al., 2015; Murray et al., 2016; Su et al., 2016), and ankle (Kelly and Beardsley, 2016; Skarabot et al., 2015). Researchers have found that RM may reduce post exercise decrements in muscle performance (Cavanaugh et al., 2016; Cheatham et al., 2015; Macdonald et al., 2014; MacDonald et al 2013; Schroeder and Best, 2015), increase posttreatment pressure pain thresholds (PPT)(Aboodarda et al., 2015; Cavanaugh et al., 2016; Cheatham and Baker, 2017; Cheatham et al., 2017a,b; Macdonald et al., 2014), and reduce the effects of post exercise muscle soreness in healthy individuals (Beardsley and Skarabot, 2015; Cheatham et al., 2015; Rey et al., 2017; Romero-Moraleda et al., 2017; Schroeder and Best, 2015). Several recent studies have also documented positive post-exercise effects of rolling for different sports (D'Amico and Paolone, 2017; D'Amico & Gillis 2017; Grgic and Mikulic, 2017; Rey et al., 2017), occupations (Kalen et al., 2017), and fibromyalgia (Ceca et al., 2017). Despite the growing body of research, there are still many unanswered questions regarding the optimal type of roller, technique, time, cadence, when to administer the intervention, and its effects

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on individuals with musculoskeletal pathology (Beardsley and Skarabot, 2015; Cheatham et al., 2015; Kalichman and Ben David, 2017).

Of interest, are the therapeutic effects of the different types of roller surfaces. A 2008 study by Curran et al., (2008) suggested that a multilevel textured surface roller produces more pressure and isolated contact area on the target tissues than a smooth surface roller (Curran et al., 2008). The researchers did not measure the therapeutic effects, but this study has become a reference standard and has prompted researchers to use multilevel rollers in their investigations (Beardsley and Skarabot, 2015; Cheatham et al., 2017a,b; Cheatham et al 2015; Schroeder and Best, 2015). What remain unknown, are the therapeutic effects of different surface type rollers. The purpose of this investigation was to measure the therapeutic effects of three different surface type pattern foam rollers with the same density, on passive knee joint ROM and PPT of the quadriceps. The researchers hypothesized that a multilevel surface roller would have a greater therapeutic effect on joint ROM and PPT than a smooth surface roller.

## 2. Methods

### 2.1. Participants and study design

Thirty-six healthy, active adults (M = 22, F = 14) were recruited via a sample of convenience and enrolled in the study. Individuals were randomly assigned into three groups of 12 participants: (1) smooth surface, (2) multilevel surface, and (3) GRID surface intervention groups (see Table 1). Participants reported partaking in recreational fitness activities (e.g. walking) and previous experience using a roller massage device within the last three years but were not currently using any devices. Participant exclusion criteria included the following: musculoskeletal, systemic, neurosensory, or metabolic conditions that would affect joint ROM or tolerance to PPT of the lower extremity, or the inability to avoid medications that may affect testing. Participant demographic information is described in (see Table 2). This pre-intervention, post-intervention randomized controlled trial was approved by the Institutional Review Board at California State University Dominguez Hills.

### 2.2. Instruments

For ROM, the baseline digital inclinometer (Fabrication Enterprises, White Plains, NY, USA) was used to measure passive knee flexion ROM. The manufacturer reported an accuracy of ± 0.5° (Kelly and Beardsley, 2016; Sterling, 2011). Digital inclinometers are valid and reliable measures of lower extremity ROM (Gnat et al., 2010; Konor et al., 2012; Roach et al., 2013; Romero-Franco et al., 2016) and have been used in prior RM investigations (Cheatham et al., 2017a,b). The (Midvale, UT) FDX pressure algometer was used to measure PPT. The manufacturer reports an accuracy error of <± 0.3% for this technology (Wagner). Digital algometry is a valid and reliable tool for measuring pressure pain thresholds (Aboodarda et al., 2015; Chesterton et al., 2007; Nussbaum and Downes, 1998; Walton et al., 2011). Algometry has also been used in prior RM research (Cheatham and Kolber, 2017; Cheatham et al., 2017a,b).

### 2.3. Instructional video and foam rollers

An instructional RM intervention video was used in this investigation (TriggerPoint, a division of Implus, LLC, 5321 Industrial Oaks Blvd., Austin, Texas 78735, USA). The video demonstrated the use of the foam roller on the left quadriceps muscle group. This video has been used in prior investigations (Cheatham et al., 2017a,b). The three foam rollers used in this investigation were commercially manufactured with similar hard hollow cores (14 cm diameter) with a moderately firm outer EVA foam. The three rollers had different surface patterns: smooth (black), multilevel (neon green), and GRID (orange) (see Fig. 1).

### 2.4. Outcome measures

The pre-intervention, post-intervention outcome measures used for this investigation were knee joint ROM and PPT. For *passive knee flexion ROM*, the participants were placed in the prone lying position. The investigator grasped the left ankle and passively flexed the left knee to the point where the knee could no longer be passively moved without providing overpressure or the point of initial discomfort and then a measurement was taken. The investigator monitored for any compensatory movement throughout the lumbopelvis and lower extremities. For *PPT*, participants were placed in the relaxed standing position. The left quadriceps muscle group was tested (2 measurements) with the algometer in the midline of the muscle group (rectus femoris) midway between the iliac crest and superior border of the patella. The 1.0-cm$^2$ probe of the algometer was placed perpendicular to the tissues and a graded force was applied at a rate of 50–60 kPa per second (kPa/sec) until the subject verbally reported the presence of maximum discomfort (Cheatham et al., 2017a,b; Pearcey et al., 2015). These outcomes have used in prior investigations (Cheatham and Kolber, 2017; Cheatham et al., 2017a,b; Lee et al., 2015; Marks et al., 2003; Peeler and Anderson, 2008).

### 2.5. Pilot study

Pilot training was conducted over two-sessions to establish intrarater reliability for passive knee joint ROM and PPT. The primary investigator conducted all the measurements and was a board certified orthopedic physical therapist with over 14 years of experience. Ten participants were independently recruited and enrolled for this portion of the investigation. The Intraclass Correlation Coefficient (ICC model 3, k) was used to calculate intrarater reliability over the two-sessions (Portney and Watkins, 2009). The results revealed good reliability for knee joint ROM (ICC = 0.95; 95% CI 0.83–0.99) and PPT (ICC = 0.94; 95% CI 0.61–0.90).

### 2.6. Procedures

Prior to testing, eligible participants reviewed and completed study related materials including the IRB consent form and demographic questionnaire. The primary investigator took all pre and post-intervention measures and was blinded from the testing procedures and allocated foam rollers. All participants underwent one session of testing that included pre-intervention measures, followed by the foam roller intervention, and then immediate post-intervention measures. All participants were tested between the hours of 10 a.m. and 2 p.m. and were instructed to not participate in any strenuous activity 5 h prior to testing. Participants were also instructed to refrain from taking any medications that would interfere with testing. All participants were blinded to the testing results and other individuals in the study.

Initially, the investigator took pre-intervention measures then left the testing area. Then, a second investigator was present and explained and demonstrated the testing procedures to each participant and answered any questions. Each participant was given their assigned foam roll (e.g. smooth, multilevel, or GRID) and followed a video that demonstrated a foam roll intervention sequence to the left quadriceps muscle group (Cheatham and Kolber, 2017; Cheatham et al., 2017a,b). The observing

**Table 1**
Data collection Process.

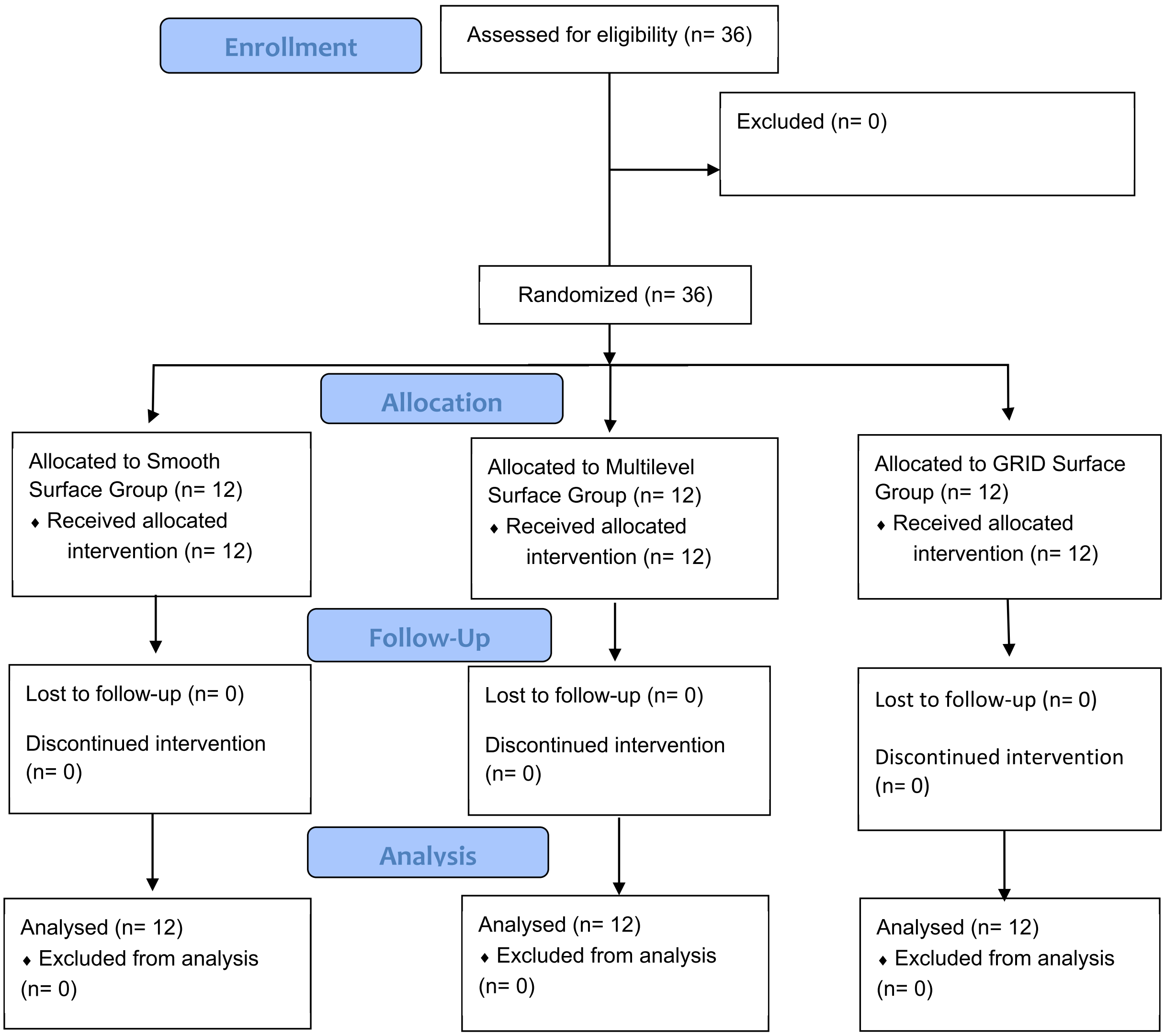


**Table 2**
Participant demographics (N = 36).

| Characteristics | Age (years) | Height (cm) | Mass (kg) | BMI (kg/m$^2$) |
|---|---|---|---|---|
| Smooth Surface Roller (N = 12) | 24.33 ± 3.47 (range 21–34) | 169.54 ± 9.88 (range 152–185) | 77.34 ± 12.56 (range 60–97) | 26.77 ± 2.57 (range 22–31) |
| Multilevel Surface Roller (N = 12) | 25.25 ± 3.60 (range 21–32) | 173.15 ± 10.13 (range 157–185) | 81.68 ± 14.96 (range 51–104) | 26.99 ± 2.98 (range 21–31) |
| GRID Surface Roller (N = 12) | 26.08 ± 6.02 (range 21–42) | 167.61 ± 9.63 (range 152–185) | 67.98 ± 16.65 (range 46–100) | 23.98 ± 4.16 (range 19–31) |

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

investigator provided no feedback to the participant. The interactive video provided a brief introduction then had the participant follow a 2-min intervention sequence demonstrated by a model in the video. The intervention divided the quadriceps group into two zones. *Zone one* was from the top of patella to middle of the quadriceps and *zone two* was from the middle quadriceps to anterior superior iliac spine. The video instructed the participant to get in the plank position and place the roller above the patella in zone one. Then roll back and forth in a longitudinal direction 4× at a cadence of 1-inch per second. Then the participant stopped the roller at the top of *zone one* and performed 4 active knee bends to 90°. For *zone two*, the participant was instructed to place the roller on the middle region of the quadriceps and repeat the rolling sequence completed for *zone one*. Once the participant completed the intervention, the primary investigator reentered the testing area and conducted the immediate post-intervention measures. These testing methods have been used in prior research (Cheatham and Kolber, 2017; Cheatham et al., 2017a,b).

### 2.7. Statistical analysis

The statistical analysis was performed by the program SPSS version 25.0 (IBM SPSS, Chicago, IL, USA). All statistical assumptions were met for the parametric and non-parametric statistics used in

**Fig. 1.** Different surface type rollers: multilevel (neon green), smooth (black), GRID (orange). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

this analysis. The descriptive statistics for subjects were calculated for age, height, body mass, and body mass index (BMI). The ANOVA statistic was used for continuous descriptive data and the Kruskal Wallis statistic for ordinal descriptive data. The ANCOVA statistic was used to measure between group differences. The independent variable was the group, dependent variable was post-test scores, and pretest scores was the covariate (Dugard and Todman, 1995). Within group differences were measured with the paired *t*-test. The effect size was also measured ($d = M_1 - M_2/\sigma_{\text{pooled}}$). The effect size values were interpreted as: > 0.70 was considered strong, 0.41 to 0.70 was moderate, and <0.40 was weak (Cohen, 1992). Statistical significance was considered $p < 0.05$ using a two-tailed test.

## 3. Results

Thirty-six participants were enrolled and completed the study (mean age = 25.20 ± 4.44 years; height = 170 ± 9.90 cm; body mass = 75.67 ± 15.51 kg; body mass index (BMI) = 25.91 ± 3.50) (Table 2). Descriptive analysis revealed no statistically significant difference between groups for age ($p = 0.64$), height ($p = 0.39$), body mass ($p = 0.14$), or BMI ($p = 0.11$). All enrolled participants completed the study with no adverse events or attrition.

### 3.1. Between group analysis

For passive knee ROM, the between group analysis revealed a statistically significant post intervention difference between the three surface type rollers [$F\ (2,32) = 3.11$, $p = 0.04$, partial $\eta 2 = 0.163$]. For PPT, a statistically significant difference was found between the three surface type rollers [$F\ (2,32) = 17.72$, $p = <0.001$, partial $\eta 2 = 0.525$].

### 3.2. Within group comparison

For passive knee ROM, within group analysis revealed a post-intervention increase of 3° ($p = 0.015$, ES = 0.42) for the smooth surface roller, 5° ($p < 0.001$, ES = 0.66) for the multilevel surface roller, and a 6° ($p < 0.001$, ES = 0.65) increase for the GRID surface roller. For PPT, a post-intervention increase of approximate 14 kPa ($p = 0.562$, ES = 0.05) for the smooth surface roller, 179 kPa ($p < 0.001$, ES = 0.44) increase for the multilevel surface roller, and a 182 kPa ($p < 0.001$, ES = 0.56) increase for the GRID surface roller was observed (see Table 3).

## 4. Discussion

The purpose of this investigation was to measure the therapeutic effects of three different surface type rollers with the same density. The between group analysis revealed a significant immediate post-intervention difference between all three rollers for passive knee flexion ROM ($p = 0.04$) and PPT ($p < 0.001$). The within group comparisons revealed statistically greater post-intervention changes in ROM and PPT for the GRID and multilevel surface rollers ($p < 0.001$) than the smooth surface roller (ROM: $p = 0.015$, PPT: $p = 0.562$).

The results of this investigation suggest that the GRID and multilevel surface rollers may have a greater immediate post-intervention effect than a smooth surface roller. These results support the work by Curran et al., (2008) that found that multilevel surface rollers produced more pressure and isolated contact area on the target tissues than smooth surface rollers (Curran et al., 2008). The therapeutic effects of the GRID and multilevel rollers may be due to the surface architecture. These roller types may provide a greater deformation of the local myofascial tissues which creates a mechanical and neurophysiological effect. For the *mechanical effect*, the pressure of the roller may change the viscoelastic properties of the myofascia by mechanisms such as thixotropy (reduced viscosity), reducing myofascial restriction, fluid changes, and cellular responses (Jay et al., 2014; Kelly and Beardsley, 2016). Clinically, these changes may be observed as a greater lengthening or “stretch tolerance” of the muscle and surrounding tissues as measured by changes in joint ROM. For the *neurophysiological effect*, the mechanical pressure from the roller may produced a global neurophysiological effect that influences tissue relaxation and local pain reduction in the target and surrounding tissues through central nervous system afferent input from the Golgi tendon reflex, mechanoreceptors (e.g. Golgi tendon organ), and nociceptors (Aboodarda et al., 2015; Cavanaugh et al., 2017; Cheatham and Kolber, 2017; Jay et al., 2014; Kelly and Beardsley, 2016; Monteiro et al., 2017a,b; Nagi et al., 2011). Clinically, these changes may be observed as a post intervention modulation of pain perception as measure by PPT using algometry. Consequently, the smooth roller surface may not be able to compress the myofascia enough to induce such mechanical and neurophysiological changes.

### 4.1. Clinical implications

The GRID and multilevel surface rollers appear to have a greater immediate post-intervention effect than the smooth surface roller. Clinicians need to consider the type of roller they are recommending to their clients. This study has built upon prior research and may provide a preliminary answer to one unanswered question regarding the therapeutic effects of different roller surfaces. Based upon these findings, clinicians may want to use a multilevel surface roller to provide a more effective intervention to the myofascial tissues.

### 4.2. Limitations

There are four limitations that warrant discussion with this study. First, this study tested participants with no pathology which

**Table 3**
Pretest, posttest descriptive results (N = 36).

| | Pretest | Posttest | Change | P-Value | Effect Size |
|---|---|---|---|---|---|
| Smooth Surface Roller | | | | | |
| Knee ROM (degrees) | 135.24 ± 7.88 | 138.19 ± 6.06 | 2.95 ± 1.82 | 0.015 | 0.42 |
| Pressure Pain Threshold (kPa) | 1247.33 ± 290.37 | 1261.45 ± 314.28 | 14.12 ± 23.91 | 0.562 | 0.05 |
| Multilevel Surface Roller | | | | | |
| Knee ROM (degrees) | 143.70 ± 8.12 | 149.17 ± 8.54 | 5.47 ± 0.42 | <0.001 | 0.66 |
| Pressure Pain Threshold (kPa) | 1142.30 ± 385.68 | 1321.95 ± 434.59 | 179.65 ± 48.91 | <0.001 | 0.44 |
| GRID Surface Roller | | | | | |
| Knee ROM (degrees) | 134.12 ± 8.35 | 140.01 ± 9.77 | 5.88 ± 1.42 | <0.001 | 0.65 |
| Pressure Pain Threshold (kPa) | 1338.58 ± 332.96 | 1521.35 ± 313.04 | 182.77 ± 19.92 | <0.001 | 0.56 |

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

limits the generalizability of the results to healthy individuals. Second, the three different surface type foam rollers were the same density and diameter. Other foam rollers with different surface patterns, diameters, densities, and material may have produced different results. Third, the immediate post intervention effects were investigated. The longer-term effects of the intervention cannot be determined. Fourth, the video only demonstrated one rolling sequence to the left quadriceps group. Testing other rolling sequences and muscle groups may have produced different results.

### 4.3. Future research

Future studies are needed to further validate the results of this investigation and to develop a consensus on the optimal surface type foam roller for specific individuals. Furthermore, research is needed to measure the longer-term effects of different types of rollers based upon surface pattern, density, diameter, and material by using similar research methods.

### 4.4. Conclusion

This investigation measured the immediate post-intervention effects of three different surface type rollers with the same density on passive knee ROM and PPT of the quadriceps musculature. The GRID and multilevel surface rollers may produce a greater therapeutic effect than a smooth surface roller due to greater mechanical tissue deformation produced by the rollers. Clinicians may want to consider such factors when prescribing RM with a foam roller as a myofascial intervention.

## 5. Clinical relevance

- The GRID and multilevel surface rollers may provider greater immediate post-intervention effects on ROM and PPT than a smooth surface roller.
- The GRID and multilevel surface roller's may provide better deformation of the myofascial tissues due to their unique architecture.
- The observed post-intervention changes in ROM and PPT may be from a local mechanical and global neurophysiological effect created by rollers.

## Conflicts of interest

The authors have no conflict of interest with this manuscript.

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