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ORIGINAL RESEARCH

ROLLER-MASSAGER APPLICATION TO THE HAMSTRINGS INCREASES SIT-AND-REACH RANGE OF MOTION WITHIN FIVE TO TEN SECONDS WITHOUT PERFORMANCE IMPAIRMENTS

Kathleen M. Sullivan, Bachelor of Kinesiology[1]
Dustin B.J. Silvey, Bachelor of Kinesiology[1]
Duane C. Button, PhD[1]
David G. Behm, PhD[1]

ABSTRACT

Background: Foam rollers are used to mimic myofascial release techniques and have been used by therapists, athletes, and the general public alike to increase range of motion (ROM) and alleviate pressure points. The roller-massager was designed to serve a similar purpose but is a more portable device that uses the upper body rather than body mass to provide the rolling force.

Objectives/Purpose: A roller massager was used in this study to examine the acute effects on lower extremity ROM and subsequent muscle length performance.

Methods: Seven male and ten female volunteers took part in 4 trials of hamstrings roller-massager rolling (1 set – 5 seconds, 1 set – 10 seconds, 2 sets – 5 seconds, and 2 sets – 10 seconds) at a constant pressure (13 kgs) and a constant rate (120 bpm). A group of 9 participants (three male, six female) also performed a control testing session with no rolling intervention. A sit and reach test for ROM, along with a maximal voluntary contraction (MVC) force and muscle activation of the hamstrings were measured before and after each session of rolling.

Results: A main effect for testing time ($p < 0.0001$) illustrated that the use of the roller-massager resulted in a 4.3% increase in ROM. There was a trend ($p = 0.069$) for 10s of rolling duration to increase ROM more than 5s rolling duration. There were no significant changes in MVC force or MVC EMG activity after the rolling intervention.

Conclusions: The use of the roller-massager had no significant effect on muscle strength, and can provide statistically significant increases in ROM, particularly when used for a longer duration.

Key Words: Flexibility, hamstrings, performance, roller-massager, self myofascial release, stretching

CORRESPONDING AUTHOR
David G. Behm
School of Human Kinetics and Recreation
Memorial University of Newfoundland
230 Elizabeth Ave.
St. John's, Newfoundland, Canada, A1C 5S7
709-864-3408 (phone)
709-864-3979 (fax)
E-mail: dbehm@mun.ca

[1] Memorial University of Newfoundland, St. John's, Newfoundland, Canada

INTRODUCTION

Appropriate increases in range of motion (ROM) associated with short and long-term flexibility training can positively affect musculoskeletal health.[1] Flexibility may be hindered for a number of reasons, one of which is fascial restrictions.[2,3] Fascia is connective tissue that surrounds muscles, nerves, blood vessels and connects structures of the body.[4] Fascia can become restricted due to injury, disease, inactivity, or inflammation.[2] These restrictions can decrease flexibility, strength, endurance, motor coordination and lead to high amounts of physical pain.[2] An array of myofascial release techniques are currently being used in order to alleviate the effects of fascia restrictions. These techniques are normally performed manually by a therapist and are held for a period of 90-120 seconds. The purpose is to stretch the fascia and facilitate histological length changes to relieve some of the symptoms of fascial restriction such as pain and restricted ROM.[3] Devices are currently being created and tested to be used to replicate myofasical release techniques so that individuals can do their own assisted fascial releases at home without the aid of a therapist.

One such device that has been shown to increase flexibility prior to physical activity is a foam roller. The foam roller is a dense foam cylinder that a person rolls their bodyweight over to increase ROM for a specific body region, as a type of self-massage. It is hypothesized that during the rolling, direct and sweeping pressure is exerted on the soft tissue causing the fascia to stretch and increase ROM.[3] Friction is also created during the rolling movement and this friction causes the fascia to increase in temperature and possibly change to a more fluid like state.[5] This change in state allows for the breaking apart of fibrous adhesions between the different layers of the fascia and restores the soft tissue extensibility.[5] In the only study published on the effects of foam rolling on flexibility; two, one minute trials of quadriceps rolling increased knee flexion ROM by 10% and 8% at 2 and 10 minutes post-rolling, respectively.[3] Hence, an acute session of quadriceps foam rolling was an effective regimen to acutely improve knee joint range of motion without a concomitant deficit in knee extensor force and activation[3].

Although beneficial in a home or clinic setting, foam rollers tend not to be conveniently portable. A more portable tool that may provide similar improvements in ROM through comparable mechanisms as foam rolling is a roller-massager. The roller-massager uses an individual's upper body strength (rather than body weight) to move the roller over the muscle to imitate myofascial release techniques. To date there are no published studies to validate its effectiveness of this device for affecting ROM. The force and duration that should be used with the roller-massager in order to facilitate flexibility changes has not yet been investigated. In addition, the use of a roller-massager and its ensuing effects on performance has not yet been examined.

The primary purpose of this study was to investigate the effects of constant intensity roller massage on ROM and subsequent performance. A secondary purpose was to determine the duration and volume required to increase ROM. It was hypothesized that multiple sets and longer durations of roller-massager rolling would result in greater ROM increases. Secondly it was hypothesized that there would be no significant impairments in subsequent force production and muscle activation.

METHODS

Subjects

Based on a statistical power analysis of prior related studies,[1,3] 17 subjects consisting of 7 men (70.2 ± 10.4 kg, 173.4 ± 8.8 cm, 22 ± 1 years) and 10 women (63.7 ± 9.8 kg, 167.2 ± 5.5 cm, 23 ± 5 years) were recruited from the university population for this study. Nine of the participants (3 males, 6 females) formed a control group. All subjects were recreationally active (participated in physical activities on average 3 times per week) and had no previous experience using a roller-massager. Exclusion criteria included any history of neurological disease or musculoskeletal injuries in the previous year. All subjects provided written consent prior to participation provided written and informed consent. Memorial University of Newfoundland Human Research Ethics Authority (HREA) approved this study.

Experimental Approach

A pre/post-test design was used for this study. The effect of massaging the hamstrings with a roller-massager with two different durations and sets was tested. Measures included flexibility (sit and reach test), muscle activation measured using electromyography (EMG), maximum voluntary contraction (MVC) force, evoked twitch force, and electromechanical delay (EMD). There were a total of four interventions (5 and 10s durations, 1 and 2 sets), which were performed on two separate visits to the laboratory; two interventions per visit on opposing legs. The two sessions within an intervention were separated by 30 minutes of rest to avoid neural cross-over effects. Control participants attended a third session where they performed the same pre/post-tests, but sat quietly for 5 minutes instead of undergoing a roller massager intervention. Sessions and interventions within the sessions were randomly allocated and sessions were separated by 24 hours. All testing was completed after a warm up on the Monark cycle ergometer at 70 revolutions per minute (rpm) and 1 kilopond (kp) of resistance for five minutes. Each session lasted approximately 30-45 minutes.

Intervention

The roller-massager by Theraband® (The Hygenic Corporation, Akron, OH) is a portable device with dense foam wrapped around a solid plastic cylinder (Figure 1). Its ridged design allows for both superficial and deep tissue massage. A roller massager is reported to offer a massage like feel[6] and it is rolled over an individual's muscle in order to replicate proposed deep tissue massage and myofascial release effects.

Subjects were informed of the protocol and were given a brief introduction to the roller-massager procedure. They were then asked to lie in a prone position with the leg of interest placed in a specially

Figure 1. *The roller-massager used in the apparatus used for this research (Theraband®, The Hygenic Corporation, Akron, OH).*

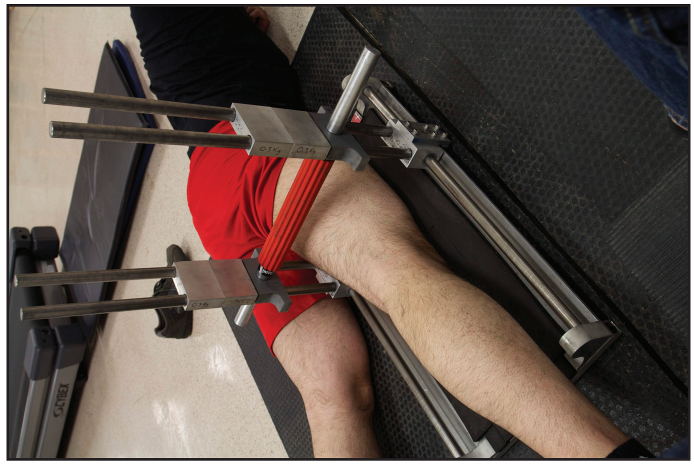

Figure 2. *The custom-made device used in the research for rolling the hamstrings with steady force and speed.*

designed constant pressure roller apparatus (CPRA) (Custom designed by Technical Services, Memorial University of Newfoundland) as seen in Figure 2. Weighted plates were added to the vertical poles and the researcher lifted the roller-massager (and weights) while the participant's leg is placed on the black padding as seen in Figure 2. The CPRA device was constructed to ensure a consistent pressure of rolling as compared to the variations that would be typical if each individual applied the roller action to their own limb. A demonstration was given on the rolling technique and the pace that would be used in the study (120 beats per minute). This pace allowed for 1 full cycle (distal to proximal and return) of the roller stick to be completed per second. The frequency was determined from pilot work where 5 subjects accustomed to rolling were asked to roll at their typical frequency. The frequency was monitored and the average frequency was used for the experiment. A roll was initiated at the distal end of the hamstrings (the popliteal fold) to the proximal end (the gluteal fold) and reversed. The frequency was maintained at 120 bpm by using a metronome for the entire rolling duration. The roller-massager intensity was maintained constant at 13 kg using the CPRA. During pilot testing, the roller-massager was rolled over a force plate by experienced individuals to determine the typical amount of force individuals would exert while rolling a muscle. Thirteen kilograms of force was determined to be the average, and thus was used for this study. Three minutes following the roller-massager intervention, hamstrings voluntary and evoked forces, activation and flexibility were measured.

Dependent Variables

Electromyography (EMG). Bipolar surface EMG electrodes were used to measure muscle activation from the hamstrings (biceps femoris) during the MVC. Electrodes were placed over the biceps femoris since its more lateral position would help ensure that the electrodes did not receive as much direct pressure from the rolling on the hamstrings. Two surface EMG recording electrodes (Meditrace Pellet Ag/AgCl discs and 10 mm in diameter, Graphic Controls Ltd., Buffalo, NY) were placed 2 cm apart over the midpoint of the muscle belly between the gluteal fold and the popliteal fold, with a ground electrode placed on the head of the fibula.[7] All electrode placements were marked with indelible ink in order to ensure accurate and consistent surface electrode placement in subsequent sessions. All skin surfaces where the electrodes were placed were shaved, abraded, and cleansed with alcohol to improve electrical conductivity.

EMG activity was sampled at 2000 Hz, with a Blackman 61 dB band-pass filter between 10 and 500 Hz, amplified (bi-polar differential amplifier, input impedance = 2 Mf, common mode rejection ratio [110 dB min (50/60 Hz), gain 1,000, noise [5 lV), and analog to digitally converted (12 bit) and were stored on a personal computer for further analysis (Dell Inspiron 6000). The integral of the EMG raw signal was analyzed over a three second period of the MVC that included the peak force, after the application of a finite infinite response (FIR) filter with a band pass of 20-500 Hz.[8]

MVC Isometric Force. While lying prone on a padded table, subjects performed a unilateral maximum voluntary isometric knee flexion exercise by contracting the limb against a strap attached at the ankle joint (the upper portion of the leg was fastened to the table in order to prevent movement artefact). The ankle strap was secured by a high-tension wire and secured onto a metal plate on the floor where isometric force was measured with a Wheatstone bridge configuration strain gauge (Omega Engineering Inc., Don Mills, Ont.). Differential voltage from the strain gauge, was amplified, converted (Biopac Systems Inc. DA 100 and analog to digital (A/D) converter MP100WSW; Holliston, MA) and monitored on a computer (Dell Inspiron 6000,) at a sampling rate of two kHz. A commercial software program (AcqKnowledge III, Biopac Systems Inc., Holliston, MA) was used to analyze the digitally converted analog data. Reliability was assessed with an intraclass correlation coefficient (ICC) which was 0.98 for MVC force and 0.93 for MVC EMG values.

Participants were instructed on how to perform a MVC and then asked to execute two unilateral hamstrings MVCs for a duration of four seconds each. The subject was coached to flex their knee as fast and as strong as they could during the MVC. Verbal encouragement was given during the MVC to motivate the subject. Evoked contractile twitches were delivered one second before and one second after the MVC. Sixty seconds of rest separated the two MVC tests. The maximum force reading was taken during the four second MVC.

Evoked Contractile Force. Evoked contractile properties were tested pre- and post-intervention to measure twitch force and EMD as an indication of changes in excitation contraction coupling and musculotendinous compliance. Hamstrings twitches were evoked with stimulating electrodes, that were constructed in the laboratory from aluminum foil and paper coated with conduction gel (Aquasonic, Fairfiled NJ) and immersed in a saline solution (5 cm width)[9]. Placement of the upper electrode was in the gluteal fold in order to stimulate the hamstrings. The lower stimulating electrode was placed at the distal portion of the hamstrings near the popliteal fold. The electrodes were not in contact with the antagonist muscles. Electrode position was maintained from test to test by outlining the electrode position with indelible ink. The amperage (maximum 1 amp) of the stimulation (Digitimer Stimulator; Model DS7H+, Welwyn Graden City, Hertforshire UK) was progressively increased until a force plateau was achieved as measured by the strain gauge. Pulse duration was maintained at 50 μs and voltage at 300 volts. All data was collected at 2 kHz and then stored on a computer (Dell Inspiron, 6000). An evoked twitch was delivered first, followed by a maximal voluntary contraction, followed by another evoked twitch. This was done to ensure that potentiation effects did not influence the desired measures.

Range of Motion. As performed previously in this laboratory,[1,10] flexibility was tested using the sit-and-reach test.[11] The sit and reach test specifically measures flexibility in the hamstrings and lower back. The subjects had one leg extended to the flexometer (Acuflex I, Novel Products Inc., USA) and the other bent with the dorsal part of their foot at a 90° angle against the opposing knee. The subjects removed their shoes and were shown how perform the sit-and-reach test correctly. Two measurements were taken to the nearest half-centimeter pre- and post-intervention. The highest score achieved was used for analysis. Reliability as assessed with an ICC was 0.96 for the sit and reach test scores.

Statistical Analysis

Initially, a 2 way repeated measures ANOVA (2x2) was performed to determine if there were any gender effects over the testing time. With no gender differences detected ($p = 0.61$), all data was subsequently analyzed with a 3 way repeated measures analysis of variance (ANOVA) (2x3x3) (SPSS, Version 17.0, Polar Engineering and Consulting). Factors included 1) testing time (pre- and post-intervention), 2) rolling durations (0, 5 and 10 s), 3) sets of rolling (0, 1 and 2). Differences were considered significant at $p < 0.05$. If significant differences were detected, a Bonferroni (Dunn's) procedure was used to identify the significant interactions. Data were reported as means $\pm$ standard deviation (SD).

RESULTS

Range of Motion (ROM)

There was a significant main effect for time with an increase in ROM from pre- (31.32 ± 2.10 cm) to post-rolling (32.68 ± 2.06 cm) of 4.3% ($p = 0.0001$) (see Figure 3A). There was also a trend toward ($p = 0.069$) a group main effect with 10 s of roller-massager rolling (32.37 ± 2.09 cm) exceeding 5 s (31.63 ± 2.08 cm) of rolling by 2.3% (see Figure 3B). Irrespective of roller-massager set number or duration and gender every participant had an increase ROM following roller-massager application (Figure 4), whereas this was not the case for the control group ($p = 0.68$) (i.e. no roller-massager application).

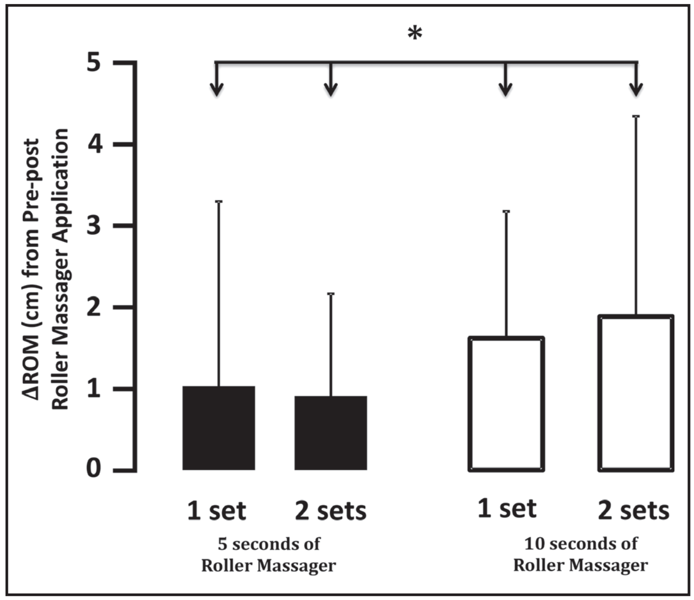

Figure 3. *Hamstring ROM after A) 1 and 2 sets of 5 seconds and B) 1 and 2 sets of 10 seconds of roller massager application. * Represents statistical significance of p < 0.001 for all post-test ROM versus pre-test conditions.*

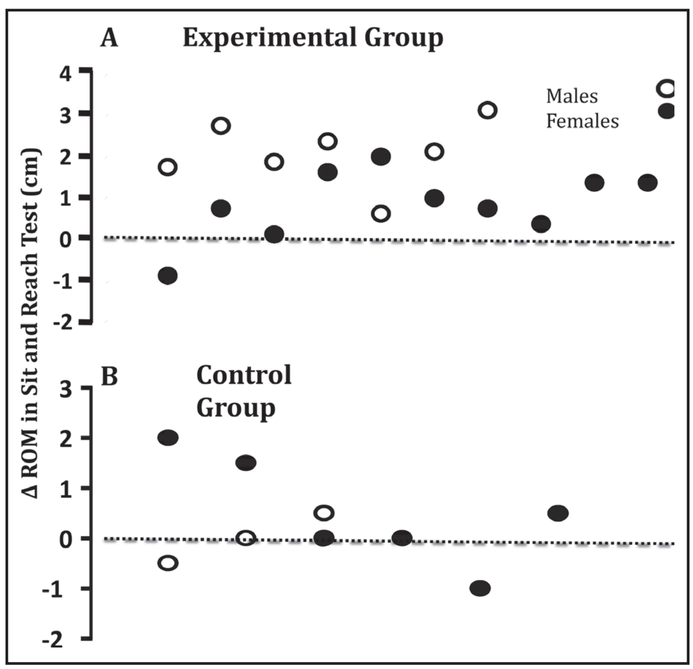

Figure 4. *Scatter plot of Δ ROM in Sit and Reach Test (cm) from pre- to post-roller massager application for male and female participants in A) experimental and B) Control group.*

Maximum Voluntary Contraction (MVC) Force and Activation

There were no statistically significant differences between the conditions for MVC force (Table 1) ($p = 0.64$) or muscle activation (Table 2) ($p = 0.71$).

Evoked Twitch Force

Main effects for sets demonstrated that the potentiated twitch force was significantly ($p = 0.016$) decreased 7.1% with 1 set (6.64 ± 0.63 kg) versus 2 sets (6.20 ± 0.66 kg) of rolling. Secondly, main effects for time showed that evoked twitch forces significantly ($p = 0.001$) decreased 10.5% from pre- (6.74 ± 0.66 kg) to post-rolling (6.10 ± 0.64 kg). There was also a significant interaction ($p = 0.044$) between sets of rolling and rolling duration that exhibited a decrease in twitch force for one set of 10 seconds when compared to one set of 5 seconds, and an increase in twitch force for two sets of 10 seconds when compared to two sets of 5 seconds

Electromechanical Delay (EMD)

There were no statistically significant differences found between the conditions for EMD (Table 3) ($p = 0.47$).

DISCUSSION

The roller-massager was developed as a portable tool for "myofascial release and deep tissue massage . . . designed to target superficial and deep tissue mobilization while providing a massage-like experience."[6] Thera-Band claims that the roller-massager is used to "help increase blood flow and circulation in targeted areas, while also helping to increase muscle flexibility and joint range of motion."[6] The most prevalent finding of the present study was that the roller-massager increased the sit and reach test for lower back and hamstrings' flexibility 4.3% without any significant voluntary performance detriment. In addition, hamstrings' flexibility increased with just 5s and 10s of rolling. However, there was a tendency for hamstrings' flexibility to increase to a greater degree with the longer rolling duration (10s), as well as an indication that hamstrings flexibility might increase with a second set of rolling.

Table 1. *Maximum Voluntary Contraction force values (mean kg ± SD).*

	Pre-roller massage	Post-roller massage
1 set of 5 s	32.01 ± 18.4	30.9 ± 19.3
1 set of 10 s	32.6 ± 16.9	30.6 ± 18.9
2 sets of 5 s	32.6 ± 20.3	31.7 ± 20.6
2 sets of 10 s	32.5 ± 17.7	32.6 ± 19.5
Control	33.9 ± 18.1	34.01 ± 17.2

Table 2. *Maximum Voluntary Contraction integral Electromyographic values (mean microvolt.sec ± SD).*

	Pre-roller massage	Post-roller massage
1 set of 5 s	40.1 ± 9.4	37.8 ± 18.5
1 set of 10 s	37.7 ± 21.6	41.1 ± 28.1
2 sets of 5 s	41.7 ± 21.5	43.9 ± 28.6
2 sets of 10 s	39.8 ± 16.6	40.5 ± 18.6
Control	46.6 ± 16.4	45.3 ± 11.5

Table 3. *Electromechanical delay values (ms ± SD).*

	Pre-roller massage	Post-roller massage
1 set of 5 s	21.8 ± 7.6	20.2 ± 5.9
1 set of 10 s	21.0 ± 6.1	21.7 ± 4.6
2 sets of 5 s	21.4 ± 6.2	22.8 ± 7.1
2 sets of 10 s	21.0 ± 4.9	22.9 ± 8.1
Control	19.5 ± 3.1	20.6 ± 3.9

As there are no other published studies on the roller-massager, an examination of foam rolling effects might be beneficial. A recent study[3] examined the effects of foam rolling on quadriceps flexibility (range of hip extension with knee flexed) for two, one minute bouts, and showed 12.7% and 10.3% increases in quadriceps' flexibility, 2 and 10 minutes after foam rolling respectively. The greater increase in ROM in this foam roller study compared to the present roller massager study might be related to either the longer rolling duration, greater rolling force (average body weight was 86.3 kg) or different muscles used (quadriceps vs. hamstrings). Either alone or in combination, the lengthened rolling duration and greater force may have transitioned more of the solid state fascia into gel-like fascia,[5] to provide a greater increase in ROM.

Foam and stick (roller massager) rolling are purported to act as self-myofascial release techniques. The pressure on the fascia from rolling may allow fascia to become soft and lengthen, permitting for a larger stretch of the muscle.[2] The most common theory used to explain the increased ROM with myofascial release is the thixotropic property of the fascia.[5]

This theory explains that when undisturbed, fascia becomes more viscous and takes on a more solid form, which can restrict movement. If heat from rolling friction, mechanical stress, massage or pressure is applied to the fascia, it can become more gel-like and pliable; allowing for a greater ROM[12,13,14,15], which in the present study may be achieved in as little as 5 or 10s.

Since it has been suggested that roller massager simulates self-myofascial release or massage techniques, massage studies may highlight other potential mechanisms. One hand,[16,17] light[18] and deep[18] petrissage massage has all resulted in an H-reflex inhibition. Massage negatively affected isokinetic torque, which was attributed to possible increases in parasympathetic input and decreased afferent feedback resulting in decreased motor unit activation[19]. As massage techniques are transmitted through the skin, the activity of the cutaneous afferents could play an important role in the excitation or inhibition of the central nervous system. Sayenko et al.[20] used non-noxious electrical plantar cutaneous afferent stimulation and reported that the stimulation elicited soleus H-reflex inhibition when applied to the metatarsals. Hence, the increased flexibility in the present study might be attributed to one or a combination of friction effects, myofascial release, or neural inhibitory mechanisms. However these possible mechanisms were not examined in this study.

Stretching has long been used as a method for improving ROM measures. As such, it is questioned whether the roller-massager ROM benefits may be comparable to stretching. Static stretching is known to improve ROM, but it can also have significant negative effects on neuromuscular performance.[1,21,22,23] Stretching places strain on the origin and insertion of the muscle and may cause damage to the sarcomeres.[24] Stretch-induced increases in muscle compliance (less stiff parallel and series elastic components) could increase the EMD[25] thereby slowing the transition between myofilament crossbridge kinetics and the exertion of tension. Furthermore, a lengthened muscle could have a less than optimal crossbridge overlap which, according to the length–tension relationship,[26] could diminish muscle force output. In the stretching literature,[1] it was reported that the elongation of tendinous tissues can have an effect on force output[27] through a reduction in either the passive or active stiffness of the musculotendinous unit (MTU).[28] From this evidence, it can be hypothesized that since there were no deficits in muscular performance in this study, the roller massager may use a different method than traditional static stretching in order to improve ROM.

In general, most stretching recommendations suggest stretching each muscle for 15-30s to achieve significant changes in ROM. A recent stretching study,[29] resulted in a 5% increase in hamstrings ROM after only six sets of 6s stretches without performance impairment. This is analogous to the 4.3% increase in sit and reach measure of hamstrings' flexibility seen in the current study. It is unknown whether prolonged roller-massager rolling would augment the positive effect on ROM, or if it would have a negative effect on neuromuscular performance.

Other massage studies employing various forms of massage have shown increases in ROM following the interventions, supporting the results of this study. Two types of massage (petrissage and tapotement) were implemented for three minutes each, increasing the plantar flexor muscles' ROM 3.7% and 3.2%, respectively with no detrimental effects on subsequent jump power.[30] This is in opposition to Wiktorsson-Moller et al who found that when massage was performed for 7-15 minutes there was a decrease in quadriceps' (isometric) and hamstrings' (isokinetic) force production.[31] This suggests that massage may only have a positive effect on joint ROM (and a neutral effect on subsequent muscular force) when used for a short duration (less than 7 minutes). Thus in the present study, the lack of significant performance impairments combined with increased ROM with the short duration of roller massager might suggest that the mechanisms underlying its effect are more related to massage and/or self-myofascial release techniques (i.e. effects of friction, self-myofascial release effects on viscoelasticity and fascial release, and/or neural inhibition) rather than static stretching mechanisms (increased muscle compliance due to mechanical strain).

Limitations of the study might include that a specially designed device was used to deliver the roller massager pressure rather than the typical application by an individual with their arms (advantage: consistent force application, disadvantage: ecological validity). Secondly, the sit and reach test involves the flexibility of the lower back and hamstrings. As only the hamstrings received roller massage, the low percentage improvements in ROM may be related to the unaffected muscles of the lower back. Clinical applications of the roller massager would typically involve multiple muscle groups and hence the extent of improvement in ROM may be expected to be greater than found in the limited application in the present study. While roller massagers could be used alone or in conjunction with regular stretching routines, its ease of application could be beneficial to individuals relaxing at home or busy at work (while seated or lying down). As well, athletes who must sit on the bench during a match may be able to help maintain the increased ROM achieved from their pre-game warm-up when it is difficult to leave the bench to stretch again.

CONCLUSION

The use of a Roller-Massager on the hamstrings muscles can provide significant sit and reach ROM increases with as little as 5-10s of use with 13 kg of pressure, with no subsequent significant decreases in voluntary performance. It is unknown at this time whether prolonged rolling or increased intensity (pressure) will prove to be more beneficial. Future studies on the roller-massager should be conducted in this area, as well as the physiological mechanisms responsible for the increase in ROM with the use of the roller-massager.

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