

The immediate effect of bilateral self myofascial release on the plantar surface of the feet on hamstring and lumbar spine flexibility: A pilot randomised controlled trial

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ABSTRACT

Background: Self myofascial release (SMR) via a tennis ball to the plantar aspect of the foot is widely used and advocated to increase flexibility and range of movement further along the posterior muscles of a proposed "anatomy train". To date there is no evidence to support the effect of bilateral SMR on the plantar aspect of the feet to increase hamstring and lumbar spine flexibility.

Aim: The primary aim was to investigate the immediate effect of a single application of SMR on the plantar aspect of the feet, on hamstring and lumbar spine flexibility. The secondary aim was to evaluate the method and propose improvements in future research.

Design: A pilot single blind randomised control trial.

Participants: Twenty-four healthy volunteers (8 men, 16 women; mean age 28 years \pm 11.13).

Method: Participants underwent screening to exclude hypermobility and were randomly allocated to an intervention (SMR) or control group (no therapy). Baseline and post intervention flexibility was assessed by a sit-and-reach test (SRT). A one way between groups analysis of covariance (ANCOVA) was conducted to compare between group outcome SRT measurements. Baseline pre-intervention and control SRT measurements were used as the covariate in the analysis

Results: There was a significant increase ($p=0.03$) in the intervention SRT outcome measurements compared to the control group, with a large effect size.

Conclusion: An immediate clinical benefit of SMR on the flexibility of the hamstrings and lumbar spine was indicated and suggestions for methodological improvements may inform future research.

Key Words: fascia; self myofascial release; anatomy trains; sit-and-reach test

INTRODUCTION

Flexibility is defined as the ability to move a single or series of joints through an unrestricted pain-free range of motion (ROM), with ROM as the degrees of freedom around a particular joint (Brigstocke et al 2013). The terms muscle length and flexibility are often interchanged, as it refers to the ability of a muscle crossing a joint to lengthen to end of range (Reese and Bandy 2010). Flexibility is vital for all movements and changes in flexibility may cause abnormal loading of the musculoskeletal system which could lead to injury (Wilson 2002; Ylinen 2008). Decreased hamstring flexibility is considered to be a predisposing factor for lower back pain (Esola et al 1996), participants with lower back pain were found with tightness in their hamstrings (Marshall et al 2009).

Fascia is a connective tissue which surrounds every nerve, blood vessel and muscle fibre in the human body resulting in the connection of bones, muscles and organs which form large networks throughout the body (Schleip et al 2012). Based on the tensegrity principle, previous studies have highlighted the presence of continuity and connectivity between fascia or muscle that may be anatomically distant from each other (Langevin 2006; Kassolik et al 2009).. Anatomical dissections have confirmed the continuity of the fascial system in the upper and lower limbs (Stecco et al 2007; 2008). A “schematic map” of the body’s fascia connections, namely “anatomy trains” has been suggested and proposed that any tension at a particular part of an "anatomy train" may have detrimental effects resulting in global decreased flexibility (Myers 1997; Myers 2014). For example, issues related to the plantar fascia may be associated with tight hamstrings and lumbar lordosis (Myers 2014). Reduced flexibility and tightness in the hamstrings (Harty et al 2005) and tightness in the calf muscles are a possible aetiological factor for plantar fasciitis (Bolivar et al 2013).

There is a correlation between hamstring and lumbar spine flexibility, indicating some degree of connectivity (Esola et al 1996; Marr et al 2011).

The "anatomy train" suggested to be most related (to injuries of) the lumbar spine and hamstrings is the superficial back line (SBL) (Myers 2009; 2014). The SBL contains the plantar fascia and short toe flexors (lumbricals, flexor accessorius and flexor digitorum brevis), the achilles and the muscle group triceps surae (gastrocnemius and soleus), the hamstrings (semimembranosus, semitendinosus and biceps femoris), sacrotuberous ligament, the fascia of the sacrolumbar area, erector spinae and finally the epicranial fascia which extends and attaches to the supra orbital ridge on the anterior surface of the cranium (Myers 2014).

Myofascial therapies cover a numerous and varied spectrum of techniques, including osteopathic soft-tissue techniques, structural integration (Rolfing), massage including connective tissue massage (CTM), instrument assisted fascial release, myofascial trigger point therapy, strain-counter strain and muscle energy technique (MET) (Simmonds et al 2012). Myofascial release (MFR) techniques have evolved as a result of current research and investigation via dissection and real time ultrasound and elastography (Chaitow 2012). However, in reviewing the literature, there is still theory and hypothesis in relation to the exact mechanism underlying the efficacy of fascial manual therapy. Pilat (2012) in the widely acknowledge text, *Fascia-The Tensional Network of the Human Body* (pp 312-313), has identified varying hypotheses and authors in the literature related to the mechanical stimuli of the fascia and the resultant types of reaction, namely;

- **piezoelectricity** linked to mechanical tension (Pilat 2003) and properties of elasticity, flexibility, elongation and resistance depend on an information flow

transmitted electrically through the connective tissue matrix (Oschmann 2003).

- fascial system is innervated by **mechanoreceptors** (Stecco et al 2008), that when manual pressure or traction is applied may create a range of responses that facilitate movement.
- **viscoelastic** properties of fascia have been observed in numerous studies and concepts for practical treatment applications have been defined by varying authors, including; Rolf (1994), Barnes (1997), Cantu and Gordin (2001) and Pilat (2003; 2009).

Self-myofascial release (SMR), works under the same principles as myofascial release and has been adapted to allow regular and frequent applications, without a therapist's intervention (Sullivan et al 2013). The difference between the two techniques relates to the individual using their own body mass to exert pressure on the soft tissue as they roll over the dense foam roller (FR) (Macdonald et al 2013) or a tennis ball on the plantar aspect of the foot (Myers 2014).

Recently the effect of SMR with a FR on flexibility and force production (MacDonald et al 2013; Sullivan et al 2013) and a comparison to postural alignment exercises and static stretches (Roylance et al 2013) was investigated. The above identified SMR research evidence, as in this study used a sit-and-reach test (SRT) as an outcome measure. The effect of self MTrP release in patients with triceps surae (calf) dysfunction focussing on MTrPs in the gastrocnemius and soleus using a FR in combination with a course of MTrP therapy, has also been investigated (Grieve et al 2013a). The use of a FR is often advocated in clinical practice and by fitness professionals in fields such as yoga and sports (Healey et al 2014; Okamoto et al 2014). Related research using therapist initiated myofascial release (MFR), has been

identified in increasing quadriceps and hamstrings ROM (Kuruma et al 2013); chronic lower back pain (Ajimsha et al 2014a) and plantar heel pain (Ajimsha et al 2014b).

In his Anatomy Trains Text (3rd edition), Myers (2014, p78-79) advocated a simple test rolling a tennis or golf ball on the plantar surface of the foot, applying slow pressure to see the effect this has on the SBL. He advocated this as a method on the effect that MFR, in one area of the “train” can have on another. Performance of a toe touch test (TT) post intervention, showed an apparent increase in ROM or “flexibility” (Myers 2014). However, from a review of available literature, no evidence was found to support this statement.

In light of the above anecdotal evidence, the primary aim of this pilot RCT was to investigate the immediate effect of a single application of bilateral SMR on the plantar aspect of each foot, on hamstring and lumbar spine flexibility. Secondary aim is to evaluate the study design/method and propose areas for improvement in future research.

METHODS

Participants

Thirty-three staff and students from the University of the West of England, Bristol initially volunteered for this study. Participants were recruited via email and announcements placed on communal notice boards. Participants were excluded if they were; under 18 years of age, unable to attain the SRT position, complained of recent (within three months) soft tissue, bony, spinal or lower limb injuries, fibromyalgia, MTrP therapy/myofascial release in the last three months and/or

contraindications to myofascial release. Additionally participants were also excluded if they exhibited hypermobility as judged by the Beighton score (Beighton and Horan 1969).

Ethical approval was granted from the School of Health and Social Care Ethics Sub Committee, University of the West of England Bristol. Informed consent was obtained from all participants and any relevant question or concerns were addressed prior to data collection.

Research Design

The study was a pilot single blind randomised control trial (RCT). After screening for inclusion and exclusion criteria and sit-and-reach test (SRT) baseline measurements, each participant was randomly assigned to either the intervention (SMR) or the control group (no therapy).

Randomisation

Randomisation was completed using an online randomisation tool "Graph Pad" <http://www.graphpad.com/quickcalcs/randomize1.cfm>. Stratified randomisation was conducted to ensure equal numbers of males and females were randomly allocated to each group.

Procedure

The overall procedure including the initial screening lasted approximately 20 minutes per participant and is depicted in a flow diagram Figure 1.

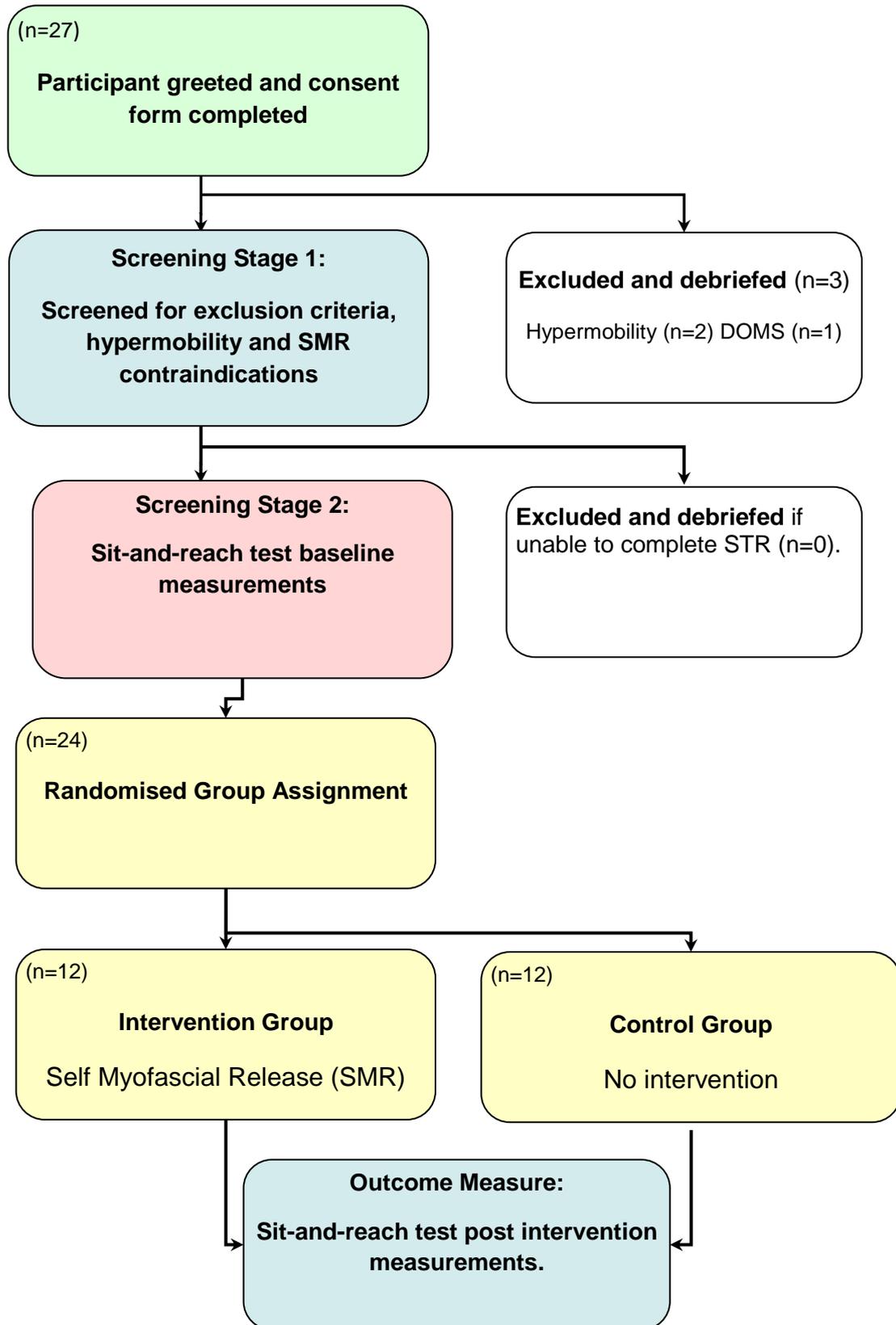


Figure 1: Flow diagram of the procedure

The Beighton score

The Beighton score was used in the screening to exclude participants with joint hypermobility. The Beighton score is a recognised and validated screening tool which assesses the ROM of selected joints (knees, elbows, thumbs, lumbar spine/hip and little fingers) (Boyle et al 2003). The score consists of a series of nine tests, with each test allocated a score of one point for successful completion. A score of four or more out of nine was used as a hypermobility exclusion point in this research (Akhtar et al 2013). All participants were asked to carry out the nine tasks, namely; place hands flat on the floor knees straight (1 point); extend or bend left and right elbows backwards (2 points); extend or bend left and right knee backwards (2 points); flex or bend your left and right thumb on to the front of your forearm (2 points) and extend or bend your left and right little finger at 90 degrees, towards the back of the hand (2 points).

Outcome measure

Baseline and post intervention flexibility was assessed by a SRT, using a sit-and-reach box (SRB) (Cranlea, Birmingham UK). The SRT outcome measure is a valid measurement for hamstring flexibility (Baltaci et al 2003), and correlations have been found between STR and lumbar spine flexibility (Grenier et al 2003). A sit-and-reach box (SRB) in measuring STR, has been recommended for use in measuring lumbar spine and hamstring flexibility (Heyward 2008). It was selected for use in the current study due to the unique ability to incorporate lumbar spine and hamstring flexibility simultaneously whilst tensioning the SBL (Mayorga-Vega et al 2014).

All participants sat with the heels/soles of their feet flat against the box, with knees fully extended, reaching forward as far as possible without breaking form and

fingertips at the correct position on the magnetic slider (Figure 2). Participants were instructed to reach forward as far as possible, with their fingertips pushing the measuring gage, and to hold the maximal reach for two seconds (Lemmink et al 2003). Three SRT measurements, held for two seconds each (Lemmink et al 2003), were recorded and the average calculated as recommended by the American College of Sports Medicine (Kaminsky and Bonzheim, 2006) and utilized by Baltaci et al (2002) and Gonzalez-Suarez et al (2012). The average of these SRT measurements across both groups was used to calculate statistical significance (Baltaci et al 2002; Gonzalez-Suarez et al 2012).

Baseline SRT measurements were taken for all participants, prior to random allocation into either the control or intervention group.



Figure 2: SRT measurement position

Self myofascial release (SMR)

Participants were taught SMR by a researcher, using a predetermined script which is sufficient for the participant to complete the intervention competently and to reduce bias (MacDonald et al 2013). Participants were instructed to roll a tennis ball on the sole of each foot from behind the metatarsal heads to the heel concentrating on the medial arch for two minutes. Participants were instructed to apply as much pressure as they could, pushing into discomfort but not pain, as greater pressures have shown to have better benefits on flexibility (Curran et al 2008).



Figure 3: Position of the tennis ball on the plantar aspect of the foot during SMR



Figure 4: SMR intervention seated

Intervention group

The Intervention procedure consisted of baseline SRT measurements, followed by four minutes of SMR (two minutes per foot) and then post intervention SRT measurements. The researcher undertaking the baseline and post SRT measurements, was blind to the group allocation.

Control group

The control procedure consisted of baseline SRT measurements, followed by participants being seated on an identical chair to the one used for the intervention and then post control SRT measurements. Participants remained seated with research supervision for 4 minutes in the same position as the SMR intervention group with both feet flat on the floor. The researcher undertaking the baseline and post SRT measurements, was blind to the group allocation.

Data analysis

Data collected was analysed using SPSS 20 (IBM). Data analysis was conducted using a 95% confidence interval and a probability (p) value of <0.05 was considered statistically significant. Descriptive data was calculated for anthropometric data (age, gender, height and weight) including mean values and standard deviation for pre, and post STR scores. Data was found to be normally distributed (Shapiro Wilk test, $p > 0.05$) and met criteria for parametric testing. A one way between groups analysis of covariance (ANCOVA) was conducted to compare the effect of SMR (independent variable) on the plantar aspect of the feet, on hamstring and lumbar spine flexibility as measured by the post-intervention and control group SRT outcome measurements (dependent variable). Participants baseline pre-intervention and control SRT measurements were used as the covariate in this analysis.

Preliminary checks were conducted to ensure the specific assumptions associated with ANCOVA were not violated namely; linearity, homogeneity of regression slopes and reliable measurements of the covariate (Pallant 2007). Partial eta-squared was used as an indication of effect size. The effect size guidelines proposed by Cohen (1988), namely; 0.01-0.05 =small effect; 0.06-0.13= moderate effect and greater than

0.14 = large effect for interpreting the strength of eta-squared, can also be used to interpret partial eta- squared (Pallant 2010).

RESULTS

Twenty-four healthy volunteers were recruited for the study (8 males and 16 females; range 19-60; mean age 28 ± 11.13). During the initial screening process, 6 potential participants were excluded via email due to current injuries and 3 were excluded on the day as they did not meet the inclusion criteria. The descriptive statistics for the baseline and post STR measurements including the "adjusted" outcome mean (controlling for the covariate) for the intervention and control groups are presented in Table 1.

Condition	Pre (Baseline)		Post(Outcome)		*Post(Outcome)		Difference	
	Mean	SD±	Mean	SD±	*Mean	**SEM±	Mean	SD±
Control	21.58	10.62	22.42	10.37	20.64	.439	0.83	1.47
Intervention	17.92	11.62	20.33	11.37	22.11	.439	2.42	1.56

Table 1: Descriptive statistics for baseline and outcome SRT measurements, including the ANCOVA *adjusted mean (controlling for the covariate). **SEM -- standard error of the mean

There was a mean difference in the baseline SRT score for the control (21.58 cm) compared to the intervention group (17.92cm), although this was not found to be statistically significant ($p=0.43$). The ANCOVA analysis adjusted for pre-intervention and control group baseline SRT scores, and indicated a significant increase in the post intervention compared to the control group SRT outcome measurements, $F=5.51$, $p=0.03$, partial eta squared=0.21. The partial eta squared statistic of 0.21 indicates a large effect size (Cohen 1988).

DISCUSSION

The results of this present study indicated that a single treatment of bilateral SMR to the plantar aspect of each foot resulted in an immediate increase in hamstring and lumbar spine flexibility as indicated by an increase in SRT scores. A statistically significant difference in SRT between the intervention and control group was identified, with a large treatment effect size established in the intervention group,

In the intervention group, only two of the twelve participations did not increase their flexibility compared to six in the control. Statistical analysis only establishes a meaningful change (Odgaard and Fowler 2010) and does not indicate the effectiveness of the intervention and whether the improvement is of clinical importance, hence an effect size was calculated (Kraemer et al 2003).

In reviewing the literature, no evidence was found regarding SMR on the plantar aspect of the foot and it's proximal effect further along the SBL. However, the findings of this pilot RCT, are the first empirical research evidence to support the apparent increase in ROM or flexibility of a toe touch test after rolling a tennis or golf ball on the plantar surface of the foot, as advocated in the text, Anatomy Trains Text (3rd edition), Myers (2014, p78-79).

The findings of this study do support the use of SMR in increasing ROM or flexibility using STR as an outcome measure (MacDonald et al 2013; Sullivan et al 2013; Roylance et al 2013). Specifically SMR using a FR, on the quadriceps, increased knee joint ROM (MacDonald et al 2013) and hamstring muscle flexibility (Sullivan et al 2013), without decreasing muscle force. Roylance et al (2013) found no statistically significant improvement in lower back, hamstrings and calf flexibility SRT scores after individual treatment by either SMR, postural alignment exercises or

static stretches. However, there were beneficial effects when SMR was combined with either postural alignment exercises or static stretching (Roylance et al 2013). Similarly, patients reported a decrease in calf pain, dysfunction and increased ankle ROM, after a combination of self MTrP release with a FR and a course of MTrP therapy (Grieve et al 2013a).

The results of the current study supported the finding of two other interventions focussing on the SBL, although neither used SMR (Spina 2011; Hyong and Kang 2013). A case study, using Active Release Technique (ART), along the affected SBL eradicated chronic hamstring pain and dysfunction (Spina 2011). A RCT, showed the positive effects of passive hamstring stretching exercises along the SBL on cervical spine range of motion and balance (Hyong and Kang 2013).

Research and clinical implications

There are acknowledged limitations and a paucity of definitive experimental evidence into the exact mechanisms behind the efficacy of manual therapy on fascial structures. Within the analysis of each group of therapies, consideration is given to hypothesised mechanical and neurophysiological explanations for the results of therapies (Simmonds et al 2012). Specifically, relevant to this study, according to Myers (2012), "anatomy trains" is only a scheme, a map which is supported by clinical observation, common sense and some initial dissection work. Myers (2012) further elaborates that "anatomy trains" is not a treatment method, but a way of seeing that has been shown to be supportive in physiotherapy, rehabilitation and manual therapy.

Further consideration should also be given to the role of MTrP therapy including self MTrP release in deactivating active and latent MTrPs in the lower limb in increasing

ROM (Grieve 2006; Grieve et al 2011; Grieve et al 2013b). The use of SMR in this study, involved the use of a rolling motion, pressure and compression often similar to trigger point (TrP) pressure release with a tennis ball along the medial longitudinal arch and from the calcaneum (distal to the fat pad) to the metatarsal heads. The location compressed in SMR, would not only contain the plantar fascia, but intrinsic foot muscles including those with known MTrPs, namely quadratus plantae, abductor hallucis and flexor digitorum brevis (Travell and Simons 1992). Therefore, it is difficult to ascertain if the SMR fascial intervention, only targeted the fascia or both the underlying muscle and associated latent MTrPs. Specific treatments aimed at the fascia, may need to review the possible impact on MTrPs, and be aware of the integral link between muscle and enveloping fascia (epimysium), muscle fibre bundles (perimysium) and individual muscle fibres (endomysium) (Dommerholt 2012).

This pilot RCT has no answer in relation to the specific mechanisms, but found an immediate clinical benefit of bilateral SMR on the plantar aspect of the foot on increased flexibility and ROM of the hamstrings and lumbar spine. The ability to increase flexibility and ROM proximally (lower limb, lumbar spine) by focussing on a distal anatomical region (plantar aspect of the foot) may have implications for future clinical practice and the management of numerous dysfunctions. In line with the findings of this study and previously identified evidence on the efficacy of MFR, SMR and MTrP therapy in increasing ROM, this may be an adjunct or alternative to some of the established forms of conventional stretching exercises. Although the benefits of stretching are known, there is debate over which conventional type of stretching such as static and dynamic stretching or proprioceptive neuromuscular facilitation (PNF) is most suitable for a particular goal or outcome (Page 2012).

Methodological considerations and limitations

The secondary aim of this pilot study was to evaluate the method, identify limitations and propose improvements in future research.

Design/protocol

The female bias (2:1), small sample size (n=24) of healthy asymptomatic volunteers may have decreased the external validity of this study. The control group ensured that any effects found were due to SMR intervention and not to confounding variables. Future studies should consider using a sham treatment in the control group in order to decrease the effects of demand characteristics and improve the internal validity of the study (Cardwell and Flanagan 2008).

Outcome measure

The SRT test is widely used in a variety of settings and with a variety of populations from athletes (Rodríguez-García et al 2008) to school aged children (Paradis et al 2014). The STR is a valid measurement for hamstring flexibility (Baltaci et al 2003) and correlations have been found between SRT and lumbar spine flexibility (Grenier et al 2003). The SRT test position is comparable to a neurological tension test (slump test), which may place the SBL on stretch. The slump test can provoke neural pain of which tight muscle and fascia adhesions are often a causative factor (Turl and George 1998), therefore participants SRT score may have been limited by lack of normal neural glide causing pain prior to reaching potential active ROM. Although there are acknowledged validity and reliability issues with the SRT (Liemohn et al 1994), it was selected for use due to the unique ability to incorporate lumbar spine

and hamstring flexibility simultaneously whilst tensioning the SBL (Mayorga-Vega et al 2014).

Hysteresis

The viscoelastic property of muscles termed “creep” can result in changes in muscles length after extended periods of strain (Taylor et al 1990; Law et al 2009). The majority of creep may occur within the first 15-20 seconds of stretch, with a high percentage in the first 0-10 seconds (Ryan et al 2010). After the multiple SRT measurements, this may be one explanation for increases that were found within the control and ultimately intervention group.

SMR Intervention

Although a strict protocol was applied with the SMR intervention group, no quantification of the pressure applied on the tennis ball was attempted. Individual differences in the efficacy of SMR may have been caused by the varying pressure applied by individuals in the intervention group. Additionally, Curran et al (2008) found benefit in ROM when compressing a FR comprised of a firmer substance compared to one made of a lower density material.

Researcher experience

Researcher experience may have been a limitation in the current study as the team consisted of final year physiotherapy students, although overseen by an experienced researcher and clinician. Limited researcher experience may be detrimental to inter and intra-rater reliability (Myburgh et al 2011).

Apart from the above methodological considerations and limitations the researchers involved in this study followed clear protocols and attempted to ensure internal validity by reducing bias through randomisation (initial intervention and control groups allocation) and blinding (researcher measuring SRT at baseline and post intervention/control was blind to group allocation).

CONCLUSION

This pilot RCT was explorative in nature on the efficacy of SMF on one area of a proposed “anatomy train” and its global effect on proximal flexibility.

This study has supplied evidence for the immediate effectiveness of SMR on the SBL and suggest that asymptomatic individuals could have an immediate increase in flexibility of the hamstrings and lumbar spine through this intervention. These preliminary findings should be interpreted with caution and should inform future research in the same area with a larger asymptomatic sample.

Further research recommendations should continue to focus on the exact mechanisms behind the efficacy of myofascial therapies.

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REFERENCES

Ajimsha M, Binsu D, Chithra S (2014a) Effectiveness of myofascial release on the management of chronic low back pain in nursing professionals. *Journal of Bodywork and Movement Therapies* 18 (2): 273-281.

Ajimsha M, Binsu D, Chithra S 2014b Effectiveness of myofascial release in the management of plantar heel pain: A randomized control trial. *The Foot* 24 (2): 66-71.

Akhtar M, Ashton F, Keating J 2013 Hypermobility: A risk factor for failure following ACL reconstruction. *British Journal of Sports Medicine* 47 (17).

Baltaci G, Un N, Tunay V, Besler A, Gerceker S 2002 Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. *British Journal of Sports Medicine* 37 (1): 59-61.

Beighton P, Horan F 1969 Orthopaedic aspects of Ehlers-Danlos syndrome. *The Journal of Bone and Joint Surgery (British Volume)* 51 (3): 444-453.

Bolívar YA, Munuera PV, Padillo JP 2013 Relationship between tightness of the posterior muscles of the lower limb and plantar fasciitis. *Foot & Ankle International* 34 (1): 42-48.

Boyle K, Witt P, Riegger-Krugh C 2003 Intrarater and interrater reliability of the Beighton and Horan Joint Mobility Index. *Journal of Athletic Training* 38 (4): 281-285.

Brigstocke G, Hearnden A, Holt C, Whatling G 2013 The functional range of movement of the human wrist. *The Journal of Hand Surgery* 38 (5): 554-556.

Cardwell M, Flanagan C 2008 Psychology AS: The Complete Companion. 2nd ed. Folens, Buckinghamshire.

Chaitow L 2012 Fascia orientated therapies: Inclusion criteria and overview. In: Schleip R, Findley T, Chaitow L, Hujing P. Fascia: The Tensional Network of the Human Body. Churchill Livingstone Elsevier, Edinburgh.

Cohen J 1988 Statistical Power Analysis for the Behavioral Sciences, second ed. Lawrence Erlbaum Associates, New Jersey.

Curran P, Fiore R, Crisco J 2008 A Comparison of the Pressure Exerted on Soft Tissue by 2 Myofascial Rollers. Journal of Sport Rehabilitation 17 (4): 432-442.

Dommerholt J 2012 Trigger point therapy. In: Schleip R, Findley T, Chaitow L, Hujing P. Fascia: The Tensional Network of the Human Body. Churchill Livingstone Elsevier, Edinburgh.

Esola M, McClure P, Fitzgerald G, Sieglar S 1996 Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. Spine 21 (1): 71–78.

Grenier A, Russell C, McGill S 2003 Relationship between lumbar flexibility, sit-and-reach test, and a previous history of low back discomfort in industrial workers. Canadian Journal of Applied Physiology 28 (2): 165-177.

Grieve R 2006 Proximal hamstring rupture, restoration of function without surgical intervention: A case study on myofascial trigger point pressure release. Journal of Bodywork and Movement Therapies 10 (2): 99-104.

Grieve R, Clark J, Pearson E, Bullock S, Boyer C, Jarrett A 2011 The immediate effect of soleus trigger point pressure release on restricted ankle joint dorsiflexion: A pilot randomised controlled trial. *Journal of Bodywork and Movement Therapies* 15 (1): 42-49.

Grieve R, Barnett S, Coghill N, Cramp, F 2013a Myofascial trigger point therapy for triceps surae dysfunction: A case series. *Manual Therapy* 18 (6): 519-525.

Grieve R, Cranston A, Henderson A, John R, Malone G, Mayall C 2013b The immediate effect of triceps surae myofascial trigger point therapy on restricted active ankle joint dorsiflexion in recreational runners: A crossover randomised controlled trial. *Journal of Bodywork and Movement Therapies* 17 (4): 453-461.

Gonzalez-Suarez B, Caralipio N, Gambito E, Reyes J, Espino R, Macatangay R 2012 The association of physical fitness with body mass index and waist circumference in Filipino preadolescents. *Asia-Pacific journal of Public health* 25(1): 74-83.

Harty J, Soffe K, O'Toole G Stephens M 2005 The role of hamstring tightness in plantar fasciitis. *Foot & Ankle International* 26 (12): 1089-1092.

Healey K, Hatfield D, Blanpied P, Dorfman L, Riebe D 2014 The effects of Myofascial Release With Foam Rolling on Performance. *The Journal of Strength and Conditioning Research* 28 (1): 61-68.

Heyward V 2008 *Evaluación de la Aptitud Física y Prescripción del Ejercicio*. Panamerica, Madrid.

Hyong I, Kang J 2013 The immediate effects of passive hamstring stretching exercises on the cervical spine range of motion and balance. *Journal of Physical Therapy Science* 25 (1): 113-116.

Kaminsky L A, Bonzheim K A 2006 American College of Sports Medicine (ACSM) resource manual for Guidelines for exercise testing and prescription (5th ed.). Lippincott Williams & Wilkins, Philadelphia.

Kassolik K, Jaskólska A, Kisiel-Sajewicz K, Marusiak J, Kawczyński A 2009 Tensegrity principle in massage demonstrated by electro- and mechanomyography. *Journal of Bodywork and Movement Therapy* 13 (2): 164-170.

Kraemer H, Morgan G, Leech N, Gliner J, Vaske J, Harmon R 2003 Measures of clinical significance. *Journal of the American Academy of Child and Adolescent Psychiatry* 42 (12):1524-1529.

Kuruma H, Taakei H, Nitta O, Furukawa Y, Shida N, Kamio H, Yanagisawa K 2013 Effects of Myofascial Release and Stretching Technique on Range of Motion and Reaction Time. *Journal of Physical Therapy Science* 25 (2): 169-171.

Langevin H 2006 Connective tissue: a body-wide signalling network? *Medical Hypotheses* 66 (1): 1074-1077.

Law R, Harvey L, Nicholas M, Tonkin L, De Sousa M, Finniss D 2009 Stretch exercises increase tolerance to stretch in patients with chronic musculoskeletal pain: a randomized controlled trial. *Physical Therapy* 89 (10): 1016-1026.

Lemmink K, Kemper H, de Greef M, Rispens P, Stevens M 2003 The validity of the sit-and-reach test and the modified sit-and-reach test in middle-aged to older men and women. *Research quarterly for exercise and sport* 74 (3): 331-336.

Liemohn W, Sharpe G, Wasserman J 1994 Criterion related validity of the sit-and-reach test. *The Journal of Strength & Conditioning Research* 8(2): 91-94.

MacDonald G, Penney M, Mullaley M, Cuconato A, Drake C, Behm D, Button D 2013 An Acute Bout of Self-Myofascial Release Increases Range of Motion Without a Subsequent Decrease in Muscle Activation or Force. *The Journal of Strength and Conditioning Research* 27 (3): 812-821.

Marshall P, Mannion J, Murphy B 2009 Extensibility of the hamstrings is best explained by mechanical components of muscle contraction, not behavioral measures in individuals with chronic low back pain. *The American Academy of Physical Medicine and Rehabilitation* 1(8): 709-718.

Marr M, Baker J, Lambon N, Perry J 2011 The effects of the Bowen technique on hamstring flexibility over time: A randomised controlled trial. *Journal of Bodywork and Movement Therapies* 15 (3): 281-290.

Mayorga-Vega D, Merino-Marban R, Viciano J 2014 Criterion-Related Validity of Sit-And-Reach Tests for Estimating Hamstring and Lumbar Extensibility: A Meta-Analysis. *Journal of Sports Science and Medicine* 13 (1): 1-14.

Myburgh C, Lauridsen H, Larsen A, Hartvigsen J 2011 Standardized manual palpation of myofascial trigger points in relation to neck/shoulder pain; the influence of clinical experience on inter-examiner reproducibility. *Manual Therapy* 16 (1): 136-140.

Myers T 1997 The 'anatomy trains'. *Journal of Bodywork and Movement Therapies* 1 (2): 91-101.

Myers T 2009 Anatomy Trains: Myofascial Meridians for Manual and Movement Therapists. 2nd Ed. Elsevier, London.

Myers T 2012 Anatomy Trains and force transmission. In: Schleip R, Findley T, Chaitow L, Hujing P. Fascia: The Tensional Network of the Human Body. Churchill Livingstone Elsevier, Edinburgh.

Myers T 2014 Anatomy Trains: Myofascial Meridians for Manual and Movement Therapists. 3rd ed. Churchill Livingstone Elsevier, United States of America.

Odgaard E, Fowler R 2010 Confidence intervals for effect sizes: Compliance and clinical significance in the Journal of Consulting and Clinical Psychology. Journal of Consulting and Clinical Psychology 78 (3): 287-297.

Okamoto T, Masuhara M, Ikuta K 2014 Acute effects of self-myofascial release using a foam roller on arterial function. Journal of Strength and Conditioning Research 28 (1): 69-73.

Page P 2012 Current concepts in muscle stretching for exercise and rehabilitation. The International Journal of Sports Physical Therapy 7 (1): 109-119.

Pallant J 2007 SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows, 3rd ed. Open University Press, Milton Keynes.

Pallant J 2010 SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows, 4th ed. Open University Press, Milton Keynes.

Paradisis G, Pappas P, Theodorou A, Zacharogiannis E, Skordilis E, Smirniotou A
2014 Effects of Static and Dynamic Stretching on Sprint and Jump Performance in
Boys and Girls. *Journal of Strength and Conditioning Research* 28 (1): 156-160.

Pilat 2012 Myofascial induction approaches. In: Schleip R, Findley T, Chaitow L,
Hujing P. *Fascia: The Tensional Network of the Human Body*. Churchill Livingstone
Elsevier, Edinburgh.

Reese N, Bandy W 2010 *Joint Range of Motion and Muscle Length Testing*. 2nd ed.
Elsevier Health Sciences, Missouri.

Rodríguez-García P, López-Miñarro P, Yust J, Sáinz de Baranda P 2008
Comparison of hamstring criterion-related validity, sagittal spinal curvatures, pelvic
tilt and score between sit-and-reach and toe-touch test in athletes. *Medicina dello
sport* 6 (1): 11-20.

Roylance D, George J, Hammer A, Rencher N, Gellingham G, Hager R, Myrer W
2013 Evaluating acute changes in joint range-of-motion using self-myofascial
release, postural alignment exercises, and static stretches. *International Journal of
Exercises Science* 6 (4): 201-319.

Ryan E, Herda T, Costa P, Walter A, Hoge K, Stout J, Cramer J 2010 Viscoelastic
creep in the human skeletal muscle-tendon unit. *European Journal of Applied
Physiology* 108 (1): 207-211.

Schleip R, Jäger H, Klingler W (2012) What is 'fascia'? A review of different
nomenclatures. *Journal of Bodywork and Movement Therapies* 16 (4): 496-502.

Simmonds N, Miller P, Gemmell H 2012 A theoretical framework for the role of fascia
in manual therapy. *Journal of Bodywork & Movement Therapies* 16: 83-93,

Spina A 2011 Treatment of Proximal Hamstring Pain Using Active Release Technique ® Applied to the Myofascial Meridians: A Case Report. Available from: <http://www.sportsperformancecentres>.

Stecco C, Gagey O, Belloni A, Pozzuoli A, Porzionato A, Macchi V, Aldegheri R, De Caro R, Delmas V 2007 Anatomy of the deep fascia of the upper limb. Second part: study of innervation. *Morphologie* 91: 38–43.

Stecco C, Porzionato A, Lancerotto L, Stecco A, Macchi V, Day J, De Caro R 2008 Histological study of the deep fasciae of the limbs. *Journal of Bodywork and Movement Therapies* 12: 225–230.

Sullivan K, Silvey D, Button D, Behm D 2013 Roller-massage application to the hamstrings increases sit-and reach range of motion within five to ten seconds without performance impairments. *The International Journal of Sports and Physical Therapy* 8 (3): 228-236.

Taylor DC, Dalton JD, Seaber AV, Garrett WE 1990 Viscoelastic properties of muscle-tendon units. The biomechanical effects of stretching. *The American Journal of Sports Medicine* 18 (3): 300-309.

Travell J, Simons D 1992 *Myofascial pain and Dysfunction: The Trigger Point Manual The Lower Extremities*. Williams & Wilkins, Baltimore.

Turl SE, George KP 1998 Adverse neural tension: a factor in repetitive hamstring strain? *Journal of Orthopaedic & Sports Physical Therapy* 27 (1): 16-21.

Wilson A 2002 Effective Management of Musculoskeletal Injury: A Clinical Ergonomics Approach to Prevention, Treatment and Rehabilitation. Churchill Livingstone, Edinburgh.

Ylinen J 2008 Stretching Therapy: for sport and manual therapies. Churchill Livingstone Elsevier, London.