Self-myofascial release vs static stretching for improving lower limb range of motion and flexibility: A systematic review

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Abstract

Background

Static stretching (SS) and self-myofascial release (SMR) are two common techniques identified to have clinical effects on joint range of motion (ROM) and flexibility. Decreased flexibility/joint ROM has been identified as an etiologic factor associated with musculotendinous strains. Despite their positive individual effects, the comparative effectiveness of SMR and SS on lower limb (LL) joint range of motion (ROM) and flexibility remains unclear.

Objective

To determine if there is a difference in effectiveness of SMR vs SS on LL ROM and flexibility in a healthy adolescent-adult population.

Methods

A systematic search was made across 7 electronic databases (Medline, Embase, Emcare, Scopus, Cochrane, Sportdiscus and PEDro) with additional grey literature searches ranging from January 2000 to July 2019. Studies of healthy 14-65 year old year olds undertaking SS and SMR interventions were included. The desired outcome measures included any LL flexibility or joint ROM measures. This review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The methodological quality of the included studies was assessed utilising a modified McMasters critical review form. Due to heterogeneity across studies, a descriptive synthesis was conducted.

Results

From a total of 684 studies, 12 studies met the final inclusion criteria. A diverse range of intervention parameters were utilised and effectiveness was assessed through multiple outcome measures. The summarised findings suggest that both SMR and SS have positive effects on flexibility, and joint ROM. Despite this consistency, the comparative effectiveness of the two interventions suggest that SMR is superior for increasing flexibility, SS is more effective for increasing joint passive ROM and both interventions are mutually effective for increasing joint active ROM.

Conclusion

The current literature assessing the effectiveness of SS vs SMR is still emerging. Despite the mixture of results of comparative effectiveness between SMR and SS, they both show potential as techniques for increasing certain ROM/flexibility of the LL.

Key words: Self-myofascial release, foam rolling, static stretching, flexibility, range of motion

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Background

Research question

Is self-myofascial release more effective than static stretching in improving LL range of motion and flexibility in a healthy adolescent-middle aged adult population?

There are many factors influencing reduced joint ROM, an example being muscle and/or fascial tightness. Myofascial tightness can be caused from increased tension from active or passive mechanisms. Actively, muscles can become shorter due to spasm or contraction or passively, muscles can become shortened due to scarring or postural adaptations [1]. In addition, fascia has more of a passive role, transmitting mechanical tension generated by muscle activity [2]. Thus both muscle and fascia both have an influence on joint ROM. Decreased flexibility or joint ROM has been identified as one of the primary etiologic factors associated with musculotendinous strains [3].

Therefore, increasing flexibility and range of motion are common outcome goals amongst clinicians, athletes and recreationally active people [4] and increases in joint ROM and flexibility may therefore be beneficial for improving performance and reducing injury risk [5].

From a clinician's perspective it could help to promote home exercise program success, increase treatment effectiveness and help to promote autonomy to patient. From a consumer perspective, it could help decrease long term money spent on physiotherapy.

Previous research has shown that SMR and SS are effective in improving joint ROM and flexibility on their own [6-8]. In addition, evidence suggests a combination of SMR andSS together is effective in increasing range of motion [4] . However, SMR hasn't previously been reviewed for its comparable effectiveness in joint ROM and flexibility to SS. For the systematic review ahead we will be reviewing the comparison of SS against SMR for improving joint ROM and flexibility.

Methods

Protocol

This review was conducted following the PRISMA statement [9] to ensure compliance with general systematic review protocol. No registration with PROSPERO was made.

Search strategy

PICO & eligibility criteria

The accepted population for this review was defined as any healthy adolescent-middle aged adults of either gender, with no LL injuries within the last 6 months. Excluded from this is any studies with participants that are <14 years,

>65 years and/or have any current or recent form of LL injuries or comorbidities, this is to attempt keeping homogeneity in participants across studies. To ensure this is followed, studies must have completed a screening questionnaire on their participants to ensure the 'healthy' requirements are met. This population was chosen as we did not want to confine to a certain injury or condition so we would have a larger clinical relevance when based on a 'healthy' population. The age exclusions were mainly due to contributing factors that may affect the results in these exclusion ages e.g. frailty in elderly and growth spurts in children.

For the intervention, SMR (a form of myofascial release performed by one's self) with the inclusion of either a foam roller, roller massager or ball equipment was included. Excluded was any studies which had interventions with myofascial release not delivered by the patient (i.e. given by therapist or another person), self massage and/or powered device-assisted self-myofascial release. This criteria was to attempt to keep a better homogeneity between studies.

The acknowledged comparator was defined as static stretches/stretching and included only those of the LL. Excluded was all other alternatives to stretches/stretching like dynamic, ballistic and/or PNF, again to keep homogeneity within the review. SS was chosen as the comparator as they traditionally have been a popular intervention choice by health professionals.

The defined outcomes were ROM and flexibility, including any LL joints/muscles. Exclusion was any upper limb ROM and flexibility. Considered outcome measures will include goniometer, knee to wall test (ankle range) and sit and reach test (hamstring range) to enhance consistency during the article screening process. This body region and outcomes were chosen as from researching the topic prior to beginning it was found that most studies completed on this topic investigated LL over upper limb and is more applicable to athletes and general healthy population.

Studies were also excluded if they were written in a non=english language, non-human subjects or published before the year 2000. As studies are limited in number, we did not want the age of the article to be a limiting factor.

Search terms

Our search terms included all of the following; **P -** Adult? or adolescent? or m?n or male or wom?n or female or athlete? or student?, **I -** self?myofascial release or myofascial release or foam roller or foam rolling or roller massage or self?roller massage, **C -** stretches or static stretches or static stretching or stretching and **O -** range of motion or ROM or flexibility. We ensured to use a range of alternative words to we don't miss any articles of interest. Also, because we have a comparator for this study, we found we were able to create a highly targeted search, making the screening process clearer.

Information sources

A total of 7 electronic databases (5 primary, 2 secondary) were chosen for this systematic review. Medline, Embase, Emcare, Scopus and Cochrane were used as they hold the largest repository of health related research. Sportdiscus and PEDro were also selected as PEDro is a specialised physiotherapy database and SportDiscus is sports specific,

which our review has clinical relevance to this area. Grey literature was also accessed to search through unpublished research and reduce the chance of publication bias. We will utilise Google search and scholar, pearling methods and Proquest for theses.

Databases were last searched on the 15/07/19. Figure 1 below is an example of a full search strategy completed using Medline.

# ▲	Searches	Results
1	adolescent/ or adult/ or middle aged/ or young adult/ or athletes/ or students/	6850463
2	(adult? or man or women or men or women or athlete? or adolescent? or student?).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	7039681
3	1 or 2	8160770
4	Musculoskeletal Manipulations/ or myofasical release.mp.	1615
5	(self?myofascial release or foam rolling or foam roller or roller massage or myofascial release).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	312
6	4 or 5	1910
7	Muscle Stretching Exercises/	1527
8	(static stretches or static stretching or stretches or stretching).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	34136
9	7 or 8	34136
10	"Range of Motion, Articular"/	47844
11	(range of motion or ROM or flexion or dorsiflexion or extension or flexibility or range of movement).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	302046
12	10 or 11	302046
13	3 and 6 and 9 and 12	47
14	6 and 9 and 12	65

FIGURE 1. Medline search example

Limitations

There have been a number of limitations encountered in this systematic review. As the systematic review is based on a comparison, there has been a less than desirable amount of studies completed comparing the two interventions together. In addition, whilst there was an adequate amount of literature accumulated from the search, there were limitations to the quality of evidence acquired thus far. In accordance to the NHMRC hierarchy of evidence [10], there is concern for how much level II evidence is available.

Study selection and designs

Once all databases were searched, results were then inputted into Endnote and then exported into Covidence. From here we could use this platform to begin the screening process and determine eligibility of studies to be included in the review. We began with title and abstract screening and then shortlisted a number of studies to screen their full-

texts.

We chose not to confine solely to RCT's as explained above the reason for this in the limitations. Therefore any study design was considered for this review.

Data collection and appraisal

Data collection process

An online data extraction spreadsheet was created so multiple researchers could access and add data from the studies chosen to include in the review. We discussed which information was needed then collectively gained this and added to the spreadsheet. As for the outcome results, data came in a variation of forms (e.g. centimetres and degrees) we chose to convert these results into a percentage change from pre to post intervention to create homogeneity across the data. Two researchers were required to cross check each study to ensure no mistakes in data collection was made.

Critical appraisal of methodological quality

A Modified McMaster Critical Review form was chosen for this review adapted from Dars et al. 2018 [11] (appendix 1) however, following the original guidelines for the McMaster Critical Review from [12] After investigating multiple other instruments the decision was made to use this mainly due to; no limitations in study designs, modifiable, has a clear scoring system and is quick and easy to use.

Risk of bias

At an individual level, through the critical appraisal using the Modified McMasters tool and data extraction stages any bias associated with the studies was identified and outlined if found in the results. Possible sources may be maturation bias, selection/sampling bias, adequate sample sizes and blinded assessors. And for risk of bias across all studies, this will be avoided via including grey literature to ensure no publication bias as well as ensuring no selective reporting was completed throughout the studies.

Analysis and interpretation

Summary measures

Percentage change from pre and post intervention was recorded for each group (SMR and SS), this was then assessed for between group differences as our main outcome measure for this review. As outcomes changed between joint range of motion (degrees) and flexibility (reach length in cm etc.), the decision was made to convert results into a percentage change.

Synthesis of results

Although best efforts were made to keep homogeneity throughout the studies selected. There was a variety of outcome measures and interventions used. For this reason, a descriptive synthesis of results was conducted. In

addition to this, the NHMRC FORM methodology [13] was followed for the interpretation of findings and clinical practice recommendations.

Hierarchy of evidence

The levels of evidence included in this study range from level II - IV. As there is a comparator being used for this review, case studies were accepted which assess the intervention versus the comparator. Ideally, studies that compare the two against a control group would give us the highest level of evidence but due to the limited number of studies available, the case studies must be included also.

Results

Study selection

The total sources identified from the initial database search were 684 after duplicates were removed. Following screening of titles and abstracts, 119 articles progressed to full text reviewing; with 106 excluded due to wrong comparator, study design, intervention, population and further duplicates. A total of 12 studies successfully met the eligibility criteria. This overall search strategy and selection process is outlined in Figure 1.

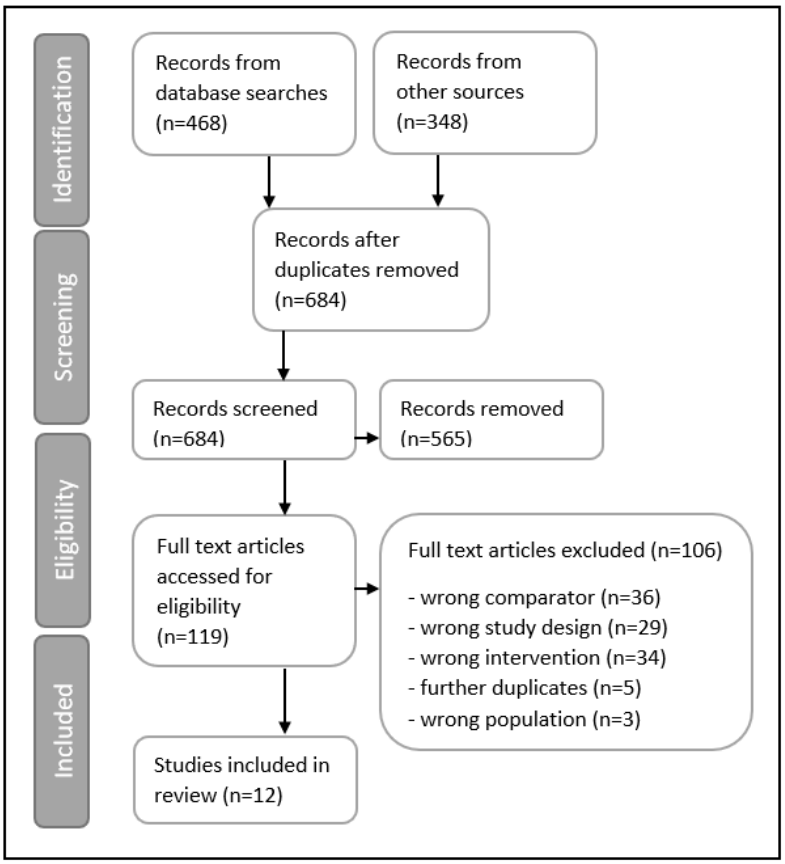

FIGURE 2. PRISMA diagram

Risk of bias

The methodological quality of the included studies was assessed using the modified McMasters critical review form. Table 1 provides a summary of the critical appraisal scores along with the level of evidence of the included twelve studies. In line with NHMRC levels of evidence, three of the twelve studies were rated as a level II (RCT) [14-16] and one as level III-1 (Psuedo-RCT) [17]. The remaining eight were rated as a level IV (case series, pre/post) [18-25]. The raw scores and percentages from the studies ranged from 11 (65%) to 15 (88%) out of a maximum score of 17 (100%). Amongst the included studies the main methodological concerns included: absence of justification for the sample size (only three addressed this) [14, 18, 19], lack of clear appropriateness of randomising (only 4) [15,19, 21, 24]; failure to avoid co-intervention [19, 20, 15, 21, 17] drop outs not addressed (Only two studies reported this) [14, 22]. Validity and reliability of outcome measures were not well addressed across a number of the included studies. Four studies failed to report both reliability and validity of measures [19, 22, 17] and an additional other failed to report validity alone [21].

TABLE 1. Methodological quality appraisal using Modified McMasters form and the NHMRC levels of evidence

Study	NHMRC level and study design	Items on Modified McMasters critical review form																	Raw score and %
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Genin [14]	II; RCT	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	15/17, 88%
Mohr, Long, Goad [15]	II; RCT	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	15/17, 88%
Sagiroglu et al [16]	II; RCT	Y	Y	Y	N	Y	-	Y	-	-	Y	Y	N	Y	Y	Y	-	Y	11/17, 65%
Keys [17]	III-1; pseudo RCT	Y	Y	Y	N	Y	N	Y	-	-	Y	Y	Y	Y	Y	N	-	Y	11/17, 65%
Halperin et al.[18]	IV; case series pre/post	Y	Y	Y	N	Y	-	Y	Y	Y	Y	Y	N	Y	Y	Y	-	Y	14/17, 82%
Hsuan et al. [19]	IV; case series pre/post	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	N	Y	Y	Y	-	Y	14/17, 82%
Kage and D'Silva [20]	IV; case series pre/post	Y	Y	Y	Y	Y	Y	Y	-	-	Y	Y	Y	Y	Y	Y	-	Y	14/17, 82%
Lee et al. [21]	IV; case series pre/post	Y	Y	Y	N	Y	-	Y	Y	Y	Y	Y	N	Y	Y	Y	-	Y	13/17, 76%
McClellan [22]	IV; case series pre/post	Y	Y	Y	N	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	14/17, 82%
Reyes [23]	IV; case series pre/post	Y	Y	Y	N	Y	-	Y	-	-	Y	Y	N	Y	Y	Y	Y	Y	12/17, 71%
Skarabot,	IV; case series	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	-	Y	14/17, 82%

Beardsley, Stirn [24]	pre/post																		
Smith et al. [25]	IV; case series pre/post	Y	Y	Y	N	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	-	Y	14/17, 82%

McMaster items: 1. Was the purpose stated clearly?, 2. Was relevant background literature reviewed?, 3. Was the sample described in detail?, 4. Was sample size justified?, 5. Were the groups randomised?, 6. Was randomising appropriately done?, 7. Was eligibility criteria clear and performed well?, 8. Were the outcome measures reliable?, 9. Were the outcome measures valid?, 10. Intervention was described in detail?, 11. Contamination was avoided?, 12. Co-intervention was avoided?, 13. Results were reported in terms of statistical significance?, 14. Were the analysis method/s appropriate?, 15. Clinical importance was reported?, 16. Drop-outs were reported?, and 17. Conclusions were appropriate given study methods and results?. Y = yes, N = no, - = not addressed

Participants and study characteristics

Detailed participant characteristics can be viewed within Table 2. The population of participants ranged from 11 to 72, with ages varying between 14- 64 years. One study did not report the age of its patients (Sagiroglu et al 2017). Overall, males dominated females, with three studies utilising a male only population [17, 25, 16]. One study failed to report number of differing gender [15].

Table 2 also provides an overview of the study characteristics of the 12 studies. A majority of studies investigated the effects of SMR or SS on flexibility/ROM alone. Of the included studies, 3 evaluated SMR or SS against other interventions, including dynamic stretching [14, 18], vibration roller [25]. Only two of the twelve studies utilised control groups [14, 15] and three used a combined intervention (SMR + SS) as an additional comparator group [15, 24, 21]. All but two studies utilised a FR for the SMR intervention, instead a small ball [20] or roller massager [23] was used. Country of origin also ranged amongst the studies in this review; these varied countries included USA [14, 15, 17, 20, 21], Taiwan [18, 25], Slovenia [24], Canada [23], India [19] and Turkey [16]; all published between the years 2003-2019.

TABLE 2. Study characteristics.

Study	N	Age	Participant Characteristics	Intervention (SMR)	Comparator (SS)	Control
Genin [14]	72	18-27	F=34, M= 38, College students recreational - moderate physical activity levels	A- glutes, hamstrings, iliotibial band , quads, calf muscles I-into mild discomfort F-1 X 60 seconds each muscle group D-60 seconds rolling T 4 visits	A- piriformis, hamstrings, quads, calf muscles I-into mild discomfort F- 1 X 30 seconds each muscle group D-30 seconds stretch T- 4 visits	Y

Halperin et al. [18]	14	22.5 +/- 3.5	F=2, M=12 Recreationally trained- min 2 days for at least 30mins of physical activity (RT or sport activity above aerobic threshold)	A-calf muscles I- 5/10 discomfort F- 3 X 30 seconds each side D-30 seconds with 10 seconds rest T-2 visits	A-calf muscles I- 7/10 discomfort F- 3 X 30 seconds each side D-30 seconds with 10 seconds rest T-2 visits	N
Hsuan et al. [19]	30	21 +/- 1.5	F= 15, M=15 Volunteers recruited from a University and surrounding community in Taiwan	A- quadriceps, hamstrings I-place as much body weight through roller as possible F- 3 X 30 seconds on each muscle group D- 30 second of rolling T- 3 visits	A- hamstrings, quadriceps I- stretching into mild discomfort F-3 X 30 seconds on each muscle group D-30 seconds stretching T-3 visits	N
Kage and D'silva [20]	30	21.7	F=23 (12 in SS group and 11 in FR group) M=7 (3 in SS group and 4 in FR group) Healthy individuals with hip adductor tightness (<35 degrees)	A- hip adductors I-nil F-2 X 30 seconds, repeat another 3X D-30 seconds of rolling, 30 second breaks T-3 visits	A- hip adductors I-nil F-2 X 30 seconds, repeat another 3X D-30 second of stretching, 30 second breaks T-3 visits	N
Keys [17]	20	22 +/-2	F=0, M= 20 Healthy college participants recruited from Southern Illinois University	A-hamstrings I-as much body weight as possible F-3 X 30 seconds per leg D-30 second of rolling, 15 second breaks T-3 visits	A-hamstrings I-stop when a stretch sensation occurs F-3 X 30 seconds stretching per leg D-30 seconds of stretching, 15 second breaks T-3 visits	N
Lee et al. [21]	30	20.4 +/- 1.2	F=0, M=30 College aged student	A-quadriceps and hamstrings I-as much body weight as possible F-3 X 30 seconds per muscle group D-30 second of rolling T-nil	A-quadriceps and hamstrings I-to the point of discomfort F-3 X 30 seconds of stretching per muscle group D-30 seconds of stretching T-nil	N
McClellan [22]	40	20.3 +/- 8.7	F= 21, M= 19 Recreational athletes	A-iliopsoas muscle I-pressure on ball subject to pain tolerance F- 3 X 1 minute D-1 minute of rolling T-2 visits	A-anterior thigh I-15% body weight F-3 X 1 minute D-1 minute of stretching T- 2 visits	N
Mohr, Long and Goad [15]	40	21.25 +/- 2.78	M= not stated F= not stated Recreationally active defined by engaging in PA 1-5 h/wk and passive HS ROM < 90 degrees as measured by SLR test	A-hamstrings I-to the point of discomfort F- 3 X 1 minute on each side D-1 minute of rolling T-6 visits	A-hamstrings I-to the point of discomfort F- 3 X 1 minute each side D-1 minute of stretching T-6 visits	Y
Reyes [23]	31	23-64	F=16, M=15 Volunteers from pharmaceutical company in Brunswick NJ	A- hamstrings I-nil F-3 X 30 seconds each side D-30 seconds of rolling, 30 seconds break T-4 visits	A-hamstrings I-nil F-3 X 30 seconds each side D-30 seconds of stretching, 30 seconds break T-4 visits	N

Sagiroglu et al. [16]	16	?	F=0, M=16 Well trained combat athletes with no experience with SMR	A= Hamstrings, quadriceps , hip and gastrocnemius I= as much pressure as they could F= 2 X 30 seconds per muscle group D= 30 seconds rolling, 10 seconds break T= 3 visits	A= Hamstrings, quadriceps, glutes, calf muscles. I= just before discomfort F= 2 X 30 seconds per muscle group D= 30 seconds stretching, 10 second break T= 3 visits	Y
Skarabot, Beardsley & Stirn [24]	11	15.3 +/- 1.0	F=5, M=6 Adolescent trained swimmers partaking in 16hrs of swimming training, 3 hrs of resistance training and at least 30mins of FR per week (for proceeding 6 months)	A= calf muscles I= to exert as much pressure on the foam roller as possible F= 3 X 30 seconds each side D= 30 seconds rolling, 15 second break T= 3 visits	A= calf muscles I= to the point of discomfort F= 3 X 30 seconds each side D= 30 seconds stretching, 15 second break T= 3 visits	N
Smith et al [25]	44	21.5 +/- 1.85	F=18, M=26 Healthy University aged	A= calf muscles I= 1 beep (for up then down phase) for 60bpm of metronome F= 3 X 30 seconds each side D= 30 seconds rolling T= 12 visits in 6 weeks	A= calf muscles I= nil F= 3 X 30 seconds each side D= 30 seconds stretching T= 12 visits in 6 weeks	N

Abbreviations: M= male, F=female, A= area,I= intensity, F= frequency, D= duration, T=time

Outcome measures (OMs)

Table 3 summarises the outcome domains and measures of the twelve studies. The two main domains included flexibility and ROM (passive and active) exclusive to the LL. Of the included studies, five investigated flexibility for hamstrings, and one study had an additional measure of quadriceps flexibility [18]. Outcome measures varied across studies including goniometer measure of active knee extension [14, 22], Sit and reach test [16-18] and Modified Thomas test [18]. The remaining seven studies assessed ROM, with variations in type (active and passive) and location of measurement. Four studies looked at active ROM for either ankle dorsiflexion (DF) [14, 21], hip abduction [19], and hip extension [20]. Remaining studies investigated passive ROM for ankle DF [24], knee flexion/extension [25] and hip flexion [15]. There was a great dissimilarity in the utilised OM tools. The most commonly used was an inclinometer, which had variations in itself, including a bubble [15], digital [20] and smartphone [19]. The remaining OM/tool included a goniometer [25], KTW test [23, 24] and digital torpedo level [21].

The large variation in OMs, created a mixture of calculation parameters for results. Some studies utilised the average score of attempts, whereas others recorded the greatest attempt as their final result. The majority of studies limited attempts to 2-3, however one study allowed unlimited tries to participants, [24]. The time taken of measurements for the studies varied from immediately to 20 minutes post intervention, and the time periods ranged from 5 days up to 6weeks.

TABLE 3. Outcome domains and measures.

Study	Outcome domains	Outcome measures
Flexibility		
Genin [14]	Hamstring (via active knee extension)	Popliteal angle hamstring test (goniometer)
Hsuan et al.[19]	Hamstring Quadricep	SRT MTT
Keys [17]	Hamstring	SRT
Reyes [23]	Hamstring (via active knee extension)	Popliteal angle hamstring test (goniometer)
Sagiroglu et al [16]	Hamstring	SRT
Passive ROM		
Lee et al.[21]	Knee flexion Knee extension	Ely's test Popliteal angle hamstring test (goniometer)
Mohr, Long and Goad [15]	Hip flexion	Bubble inclinometer
Skarabot, Beardsley & Stirn [24]	Ankle dorsiflexion	KTW
Active ROM		
Halperin et al. [18]	Ankle dorsiflexion	KTW
Kage and D'Silva [20]	Hip abduction	Smartphone inclinometer
McClellan [22]	Hip extension	Digital inclinometer
Smith et al. [25]	Ankmixturele dorsiflexion	Digital torpedo level Wall stretch test- lunge forward with full knee extension.

Abbreviations: SR= sit and reach, MTT= modified thomas test, ROM= range of motion, KTW= knee to wall

Summary of results

The results of the twelve included studies are displayed in Table 4. This section of the review summarises these findings in relation to LL flexibility, active ROM and passive ROM when comparing SMR to SS. Overall, all changes for within and between groups were positive for both interventions.

Effects of SMR vs SS on Flexibility

Out of the twelve included studies, five evaluated the effects of SMR vs SS on flexibility. Collectively all five concluded SMR had a greater effect than SS on flexibility. However, of these five, only one study had statistical significance between group differences. The study by Sagiroglu et al. (2017) [16] found SMR had a 3.4 % greater difference over SS for hamstring flexibility via a SRT. Of the remaining four studies, two studies [14, 18] both

found positive significant differences for within group changes of the two interventions for hamstring and quadriceps flexibility; despite the non-significant between group differences. The final two studies did not manage to report/conclude statically significant findings for between group differences. One of these studies had poor reporting of results, which created difficulty for interpretation [22].

Effects of SMR vs SS on Passive ROM

Three of twelve studies investigated the impact of SMR vs SS on passive ROM of LL joints. Despite the heterogeneity in muscular areas of measurement, the majority concluded that SS had greater effects than SMR on various LL ROM. The study by Skarabot, Beardsley and Stirn (2015) [24] was the only one of three which had a statistically significant finding; whereby SS had a 3.44% greater effect than SMR on passive ankle dorsiflexion via a weight bearing lunge. Smith et al. (2019) [25] considered passive ROM for two separate measures (KF/KE) and despite non-significant between group differences, found significant within group differences for both KF and KE during SS and KE alone for SMR. The remaining study by Mohr, Long and Goad (2015) [15] indicated there was no significant within and between group differences for hip flexion ROM for both interventions.

Effects of SMR vs SS on Active ROM

The effect of either SS or SMR on LL active ROM was investigated by four studies. Of these studies, final conclusion were divided, with two establishing SMR as the superior intervention [19, 21] and the remaining two studies concluding the opposite [20, 23] however, only two of these overall findings were statistically significant. The study by Kage and D'SIlva (2017) [20] concluded that SS had a 7.76% greater effect on active hip extension ROM when compared to SMR. Lee et al. (2018) [21] found a 11.4% greater difference for SMR compared to SS for active ankle DF ROM. The remaining two studies both had non statistically significant between group conclusions, however one study still achieved results which showed significant pre-post differences of ankle ROM for both interventions [23]. The final study by Hsuan et al. (2016) [19] had nil reports of significant differences within and between the two intervention groups.

TABLE 4. Summary of results

Study	**SS** **(within group difference)**	**SMR** **(within group difference)**	**Conclusion** **(between group difference)**
Flexibility			
Genin [14]	% change ↑ 5.18% *	% change ↑ 6.57% *	1.39% SMR > SS
Hsuan et al. [19]	MTT: % change ↑5.6%* SRT: % change ↑5.9% *	MTT: % change ↑ 9.38%* SRT: % change ↑ 11.81%*	3.78% SMR >SS 5.91% SMR>SS
Keys [17]	% change ↑ 33.02 %	% change ↑ 28.9	4.12% SMR > SS (?)

Reyes [23]	NR	NR	SMR > SS (?)
Sagiroglu et al. [16]	% change ↑ 9.9% *	% change ↑ 13.3% *	3.4% SMR > SS *
Passive ROM			
Lee et al. [21]	KF: % change ↑2.1%* KE: % change ↑ 4.4%*	KF: % change ↑0.6% KE: % change ↑4.6%*	1.5% SS > SMR 0.2% SMR > SS
Mohr, Long and Goad [15]	% change ↑ 12.26%	% change ↑ 6.88%	5.38% SS> SMR
Skarabot, Beardsley & Stirn [24]	% change ↑ 6.2% *	% change ↑ 2.76% *	3.44% SS > SMR *
Active ROM			
Halperin et al.[18]	% change ↑ 5%*	%change ↑ 3.6%*	1.4% SS> SMR
Kage and D'Silva [20]	% change ↑ 32.75 % (?)	% change ↑ 44.1 % (?)	11.35% SMR > SS (?)
McClellan [22]	% change ↑ 21.46% *	% change ↑ 13.7% *	7.76% SS > SMR*
Smith et al. [25]	% change ↑12.9% *	% change ↑ 24.3% *	11.4 SMR > SS *

↑= increase, ↓= decrease, ↔ no change, (+)= positive change/improvement, (-)= negative change *=statistical significance (P<0.05), (?)= significance not reported.

Abbreviations: MTT= modified thomas test, SRT- sit and reach test, NR= not reported

NHMRC recommendations

The analysis of the body of evidence utilising the NHMRC FORM framework can be seen summarised in table 5. Although overall the evidence had satisfactory level of bias and evidence base with reports of clinical impact and good generalizability, the difference in results and inconsistency throughout brought the grade of recommendation down. Therefore this evidence provides some support for recommendations, however, care should be taken in its application.

TABLE 5. NHMRC recommendations from the body of evidence

Component	Grade	Comments
1. Evidence base	C Level III studies with low risk of bias, level I or II studies with moderate risk of bias	Total of 12 studies with a total of 378 participants Level II evidence: 3 Level II-1 evidence: 1 Level IV evidence 8
2. Consistency	C Some inconsistency reflecting	Statistical significance consistently reported (three studies had nil reports of this) Heterogeneous intervention parameters;

	genuine uncertainty around clinical question	3 main outcome domains (flexibility, passive ROM and active ROM), but varied outcome measures;
3. Clinical impact	B Substantial	All but 1 study reported clinical importance however these recommendations differ between studies
4. Generalisability	B Populations studied in the body of evidence are similar to the target population	Some variations in evidence base population to target populations, 3 studies with male only population and varying levels of PA; All studies had exclusions of participants with any comorbidities/injures of the LL;
5. Applicability	C probably applicable to Australian healthcare context with some caveats	Applicable to some health professionals in Australia Difference in results provides some caveats
Grade of recommendations	C Body of evidence provides some support for recommendations but care should be taken in its application	Overall the body of evidence has a moderate-low risk of bias and good generalisability, although it lacks uniformity in results and consistency throughout the studies providing some caveats for clinical practice.

Discussion

Summary of evidence

In consideration of the limited investigation of the comparative effectiveness of SMR and SS on ROM/flexibility previously, this systematic review aimed to review recent literature and synthesise the body of evidence to investigate the topic. A modest evidence base consisting of twelve studies (2003-2019), with varying research types were utilized. Across the studies there was consistent positive outcomes for ROM and flexibility in both SMR and SS. On a comparative level, the summarised findings overall suggest that the effectiveness of SMR vs SS is mutual, but for individual outcomes is varied. Despite more than half (eight) of the included studies showing SMR had greater effects on ROM/flexibility, only two studies were statistically significant. Two of the total 12 studies had significant findings for SS having greater effects over SMR, but was limited to only ROM outcomes. The mixture in results suggest that both interventions are effective/appropriate warm-up techniques for increasing joint active ROM, SS alone is most effective for passive ROM and SMR is the most effective technique for enhancing LL flexibility, especially of the hamstrings.

Despite coming to some sound conclusions on the information above, the research is limited in its uniformity in the way of outcome measures, body parts and intervention parameters (frequency, duration, time). When assessing the evidence using the NHMRC FORM framework to give grades for recommendations these differences lowered the grade to a C overall. Therefore, only partial support for recommendations can be made and when applying the above evidence, care should be taken.

Effects on flexibility

Results suggest that SMR has superior effects for flexibility. There was consistency of measurement areas across the studies, as all results investigated hamstring flexibility, Despite 5/5 studies concluding SMR having greater effects, only 1/5 studies was statistically significant. The notable differences in significance of the one study by Sagiroglu et al. (2017) [16] may be due to the exclusiveness of an all male population, which were very physically active (combat athletes), as opposed to populations of college students or volunteers with moderate to nil reports of PA levels. This creates difficulty for generalisability as results are currently only relevant to males. The study may have had more significant results given the difference in intervention parameters, whereby measures were taken 6 minutes post intervention, as opposed to immediate measures. Clinically, this finding suggests an intervention of SMR may increase hamstring flexibility. Our recommendation to increase LL flexibility follows that of the Sagiroglu et al. (2017) [16] study suggesting to foam roll 2 X 30 second bouts on each muscle group with a 10 second break between repetitions.

Effects on Passive ROM

Overall, the SS intervention showed greater effects on LL joint passive ROM. For the one statistically significant study [24], findings were specific to passive ROM for ankle DF. The heterogeneity of the areas being measured (i.e. hip, knee and ankle) across the studies may have impacted the current findings, as no one study targeted the same area. The exclusiveness of an adolescent age population may have impacted the results. Clinically the findings suggest that SS may enhance joint passive ROM more than SMR. Our recommendation to increase LL passive ROM follows that of the Skarabot, Beardsley and Stirn (2015) [24] study suggesting to SS 3 X 30 seconds with 15 second breaks in between.

Effects on Active ROM

Results were mixed as both interventions were found to increase different joint active ROM. Only 2/4 studies investigating active ROM outcomes were statistically significant. These results suggest that SS is greater than SMR for increasing active hip extension [20] and SMR is greater for increasing ankle DF [21]. Due to the conflicting conclusions, there is limited support to suggest favouring the effects of one intervention over the other. This overall mixed outcome is expected as multiple studies have shown that both SMR and SS improve joint ROM individually [5,7,8] The notable differences in significance of the study by Reyes (2012) [23] may be due to its difference in intervention parameters, as it had increased exposure to SMR and SS (i.e 60 seconds). Clinically, there is no direct recommendation. A technique could be utilized depending on the accessibility of equipment and space,

Limitations

There are some limitations to this systematic review, like any research. Overall the methodological quality was of a good standard. Areas of concern included a majority of the studies not justifying their sample size and the design of the studies allowed for co-intervention. Although a majority of the outcome measures had good psychometric values, many of the studies did not state this, or some used OMs with poor psychometric values. Other concerns

included lack of reporting drop-outs and randomizing methods being inappropriate or not reported.

The evidence used dated back to 2003 as there has previously not been another systematic review performed for this comparison. For this reason we chose to use a study performed in 2003 which increased our data range This suggests that this study was not recent evidence and could skew our results. Our search strategy may have been too broad, resulting in limited evidence to conclude that one intervention is better than the other due to heterogeneity in interventions and outcomes, and overall mixed results. Each intervention has its own effectiveness for the different outcome domains.

Conclusion

The overall summarised findings suggest there was consistent findings for greater effectiveness of SMR for flexibility and mixed findings for both joint passive and active ROM. Despite positive outcomes for all measures, there is a lack of uniformity in terms of study populations, intervention parameters, muscles/joints measured and outcome measures/tools.

From a clinical point of view, the mixture in results may create freedom of choice for both clinician and patient. Both techniques could be utilised depending on the desired outcome and individualized preference/ appropriateness. The aspect of cost could mean SS may be more appropriate for some patients as it has no associated funds for equipment as SMR does. From the perspective of clinicians, there may be a favour for implementing SS as it is easier technique to teach and complete by the patient at home.

Future research

Future research would benefit from studies that focus on a more defined population group. In addition, there would be benefit in future research investigating specific joints for ROM changes or muscle group for flexibility changes to help with proposition of clinical recommendations. Methodological sound RCTs that are conducted with larger sample size, equal gender distribution and longer term follow up would assist with homogeneity and quality in future systematic reviews.

Implications for practice

The body of evidence supports the view that both SMR or SS have positive impacts on flexibility and ROM of the LL. Although they are techniques which could be considered for the warm-up and preventative purposes of musculoskeletal injuries, it must be considered that the current review identifies evidence which can provide only moderate support for recommendations as there is some methodological concerns; therefore care should be taken with its application.

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Appendices

Appendix 1. Modified McMasters critical review form

S3 – Modified McMaster tool

Modified McMaster Critical Review form

Fields in 'red text' have been added. Maximum score = 17 (depending on the type of study, for example, if study was not a randomised controlled trial then randomisation components were marked as NA thus changing the total score).

Assessment Components	Yes	No	Not addressed	Not Applicable
Study Purpose				
Was the purpose of the study clearly stated?	1			
Literature Review				
Was relevant background literature reviewed?	2			
Study Design				
RCT				
cohort				
single case design				
before and after				
case control				
cross sectional				
case study				
Sample	**Yes**	**No**	**Not addressed**	**Not Applicable**
Was the sample described in detail?	3			
Was sample size justified?	4			
Were the groups randomised?	5			
Was randomising appropriately done?	6			
~~Was pcs planks measure reliable (moderate or~~ Was eligibility criteria clear and performed well? ~~good)~~	7			
Outcomes	**Yes**	**No**	**Not addressed**	**Not Applicable**
Were the outcome measures reliable?	8			
Were the outcome measures valid?	9			
Intervention				
Intervention was described in detail?	10			
Contamination was avoided?	11			
Cointervention was avoided?	12			
Results	**Yes**	**No**	**Not addressed**	**Not Applicable**
Results were reported in terms of statistical significance	13			
Were the analysis method/s appropriate?	14			
Clinical importance was reported?	15			
Drop-outs were reported?	16			
Conclusions and clinical implications	**Yes**	**No**	**Not addressed**	**Not Applicable**
Conclusions were appropriate given study methods and results?	17			