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Review Article

Meta-analysis of randomized controlled trials on the flexibility and performance of muscle stretching compared with myofascial release

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Abstract: The purpose of the present study was to compare the effects of muscle stretching and myofascial release on muscular flexibility and performance. PubMed, Cochrane Library, Embase, Physiotherapy Evidence Database (PEDro), and Google Scholar were searched for studies published before July 2019. Studies comparing muscle stretching with myofascial release (SAFM), muscle fascia release (MFR), and/or foam rolling (FR) were included. Clinical outcomes analyzed included range of motion (ROM), distance of motion (sit to reach scores and knee to a wall), and muscle strength. A total of 23 articles, totaling 443 cases, were included in this study. Results showed that ROM was significantly improved after muscle stretching, compared with myofascial release (MD=-1.44 [-2.66, -0.22], P=0.02). Myofascial release and muscle stretching did not show significant differences in terms of distance of motion (MD=0.04 [-0.32, 0.40], P=0.82). However, the effects of muscle stretching on muscle strength were significantly lower than those obtained by myofascial release (MD=0.14 [0.06, 0.21], P=0.0005). Muscle stretching increased flexibility, compared with muscle fascia release. Interestingly, muscle fascia release was more efficient in improving muscle strength. Present findings, however, require more high-quality studies with long-term follow-ups for confirmation.

Keywords: Myofascial release, muscle stretch, muscle flexibility, muscle strength, meta-analysis

Introduction

Limber up is an ordinary preparatory routine. It is performed to enhance muscle performance and reduce the risk of injury. Flexibility training has often been used in combination with this pre-exercise activity, aiming to improve range of motion (ROM) [1].

Fascia restrictions often come in response to injury, disease, inactivity, and inflammation, leading to facial tissue dehydration and loss of elasticity. This induces the fascia to wrap around the traumatized area, leading to the formation of a fibrous adhesions. The latter has been shown to decrease soft-tissue extension and induce pain. This reduces rational muscle mechanics, such as muscle length, muscle tension, joint range of motion, strength, endurance, and motor coordination. Myofascial release (MFR) therapy, the technique of manual therapy invented by Barnes [2], reduces restrictive barriers and fibrous adhesion seen between layers of facial tissue. SMR works with the same principles as myofascial release. Foam rolling can be applied to various rehabilitation and training programs, promoting soft-tissue extension, enhancing joint ROM potentials, and promoting skeletal muscle function [3]. As part of the preparatory period, stretching is commonly used. The regular warm-up routine consists of substantial exercise components (running, cycling) for muscle stretching, in which the muscle is held in an elongated position for 12-60 seconds. Neither static nor dynamic stretches have been shown to acutely increase ROM. Indeed, short-term performance changes, measured shortly after static stretching (-3.7%), dynamic stretching (+1.3%), and proprioceptive neuromuscular facilitation (-4.4%), have been shown to be typically small-to-moderate in magnitude [4].

The objective of the current meta-analysis was to investigate the effects of MFR and MS on muscle flexibility and strength, aiming to identify the most effective treatment between the two.

Evidence acquisition

Objectives, literature retrieval strategies, inclusion and exclusion criteria, results measurement, and statistical analysis methods were prospectively investigated in systematic reviews, meta-analyses, and observational studies.

Literature-search strategy

Relevant studies were scanned through July 2019 without restrictions on regions, publication types, or languages. Search keywords included "muscle fascia release", "myofascial release", "foam rolling", and "muscle stretch". A comprehensive and structured literature search was performed using PubMed, Cochrane Library, Embase, Physiotherapy Evidence Database (PEDro), and Google Scholar. A total of 23 studies, including 443 cases, eventually met the inclusion criteria.

Inclusion and exclusion criteria

Randomized controlled trials (RCTs) that compared MFR and MS in terms of at least one of the quantitative outcomes of interest across all groups were included. Review articles, case reports, editorials, experimental animal studies, and letters to the editor were excluded.

Data extraction and outcomes of interest

The literature search and work evaluation was performed, independently, by two researchers. Disagreements between the two researchers were solved by discussion with a third researcher. Primary outcomes studied included muscle strength and flexibility, as well as body flexibility, including distance differences and range of motion. Range of motion levels were subdivided based on the different joints implicated. Distance was divided based on the different types of tests.

Quality assessment and statistical analysis

Methodological quality of the RCTs was assessed using Cochrane's risk of bias tool [5]. Review Manager 5.0 (Cochrane Collaboration, Oxford, UK) was used for statistical analysis [5]. Odds ratios (OR) were used to compare continuous variables. Moreover, 95% confidence intervals (CIs) were reported in all results. For studies reporting continuous data as mean and range values, techniques described by Hozo [6] were employed to calculate the standard deviation.

A random-effects model was used in case of heterogeneity between studies. Otherwise, a fixed-effects model was used [5]. For example, a fixed model was used for comparisons of distance-change, strength, and jump levels between MFR and MS, with I^2=29%, I^2=0%, and I^2=0%, respectively. Moreover, in subgroup analysis of distance changes, with an I^2=29%, a fixed model was used. In contrast, a random model was used for comparing the range of motion and for subgroup analysis of range of motion, with I^2=75% and I^2=86%, respectively.

Subgroup analysis was adapted to compare improvements in the range of motion between different joints, including increases in sit to reach, as well as other tests. Funnel plots were used for identification of potential publication bias.

Evidence synthesis

According to predefined inclusion criteria, twenty-three studies, including 884 cases (443 cases of MFR and 441 cases of MS), were approved for final analysis (**Figure 1**). All included studies were full-text publications. References cited in these studies did not include further studies for inclusion in the meta-analysis.

Characteristics of eligible studies

All included studies were RCTs with a level of evidence 2b.

Methodological quality of the included studies

Included studies were assessed using Cochrane's risk of bias tool. Fourteen articles did not have a clear description of their random sequence generation approach. In addition, eleven articles did not thoroughly describe their allocation concealment. Of these, two had a high risk of bias. Moreover, two studies showed a high risk for incomplete outcome data. Only one article had a high risk of selective reporting. All included studies showed a low risk of blinding participant, personnel, and outcome assessment due to the difficulty associated

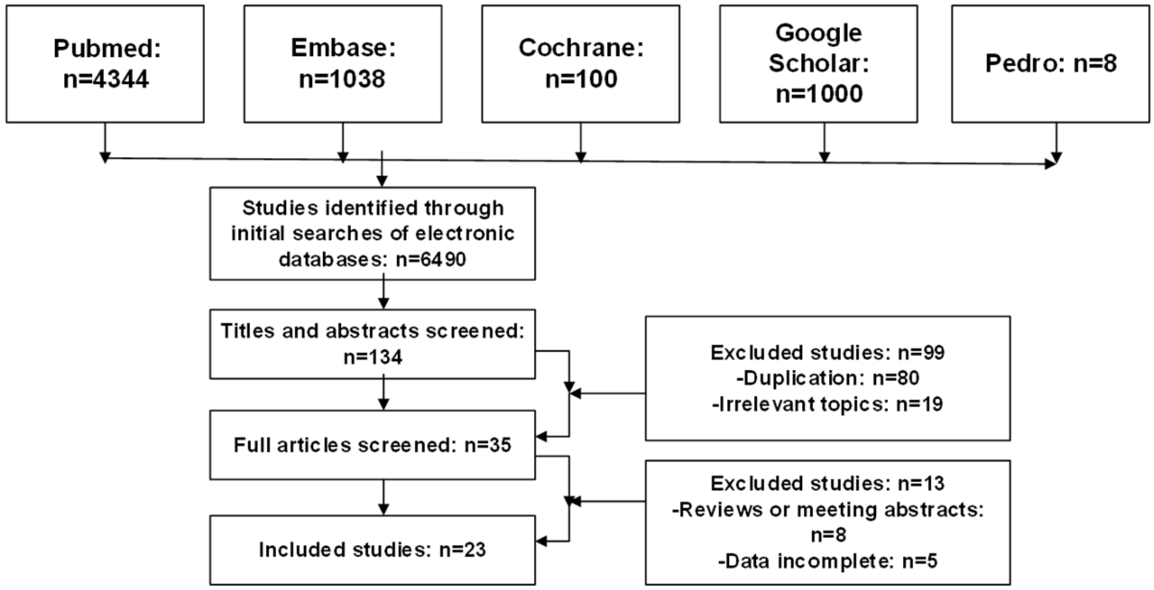

Figure 1. Flow diagram of studies identified, included, and excluded.

with the experimental approach. No other bias could be detected in the articles (**Figure 2**).

Primary outcomes

Distance change: Pooling of data from eight studies [1, 7-13], including 329 patients, was performed to assess changes in distance. Results showed no significant differences between the MFR and MS groups (MD=0.04 [-0.32, 0.40], P=0.83) (**Figure 3**). The sit to reach test was evaluated in six studies [1, 8-11, 13] (MD=0.21 [-0.25, 0.67], P=0.38). Of these, one study [12] investigated knee to wall distance and one study [7] investigated hamstring flexibility distance. Neither of the distance measurements showed significant differences between the three studied groups.

Range of motion change: Seventeen studies [10, 11, 14-28] were pooled to assess changes in the range of motion, including 654 cases. Results showed significant differences between MFR and MS groups (MD=-1.44 [-2.66, -0.22], P=0.02) (**Figure 4**). Three studies [19, 20, 27] compared changes in ankle joints, 3 studies [22, 25, 28] compared changes in knee flexion, and three studies [11, 17, 18] compared changes in knee extension angle. One study [22] compared the 3 knee measurements, of which knee flexion data was chosen for analysis. Two studies [14, 21] compared the Glenohumeral Internal Rotation (GH IR) angle and 4 studies [15, 23, 24, 26] compared hip flexion. Moreover, one study [10] compared the Modified Thomas degree, while another study [16] did not investigate the joint movement. Finally, only one study [26] reported dynamic muscle stretching. The other sixteen reported static muscle stretching.

Muscle strength: Five studies [10, 14, 19, 23, 25], including 200 patients, evaluated muscle strength from different muscle regions based on different contract modes. Pooled data showed significant improvements in muscle strength in the MFR group, compared with the MS group (MD=0.14 [0.06, 0.21], P=0.0005) (**Figure 5**). Static muscle stretching was selected for muscle stretch analysis.

Secondary outcomes

Only two studies [10, 18], including 48 cases, compared move-jump levels between the two groups. Pooled data showed no significant differences (MD=-0.03 [-0.59, 0.54], P=0.93) (**Figure 6**).

Subgroup analysis

Comparison of different joints: The two groups showed no significant differences in the ankle joint (MD=-0.47 [-1.01, 0.08], P=0.09), knee flexion (MD=-0.55 [-2.40, 1.29], P=0.56), and knee extension (MD=-1.17 [-3.62, 1.28], P=

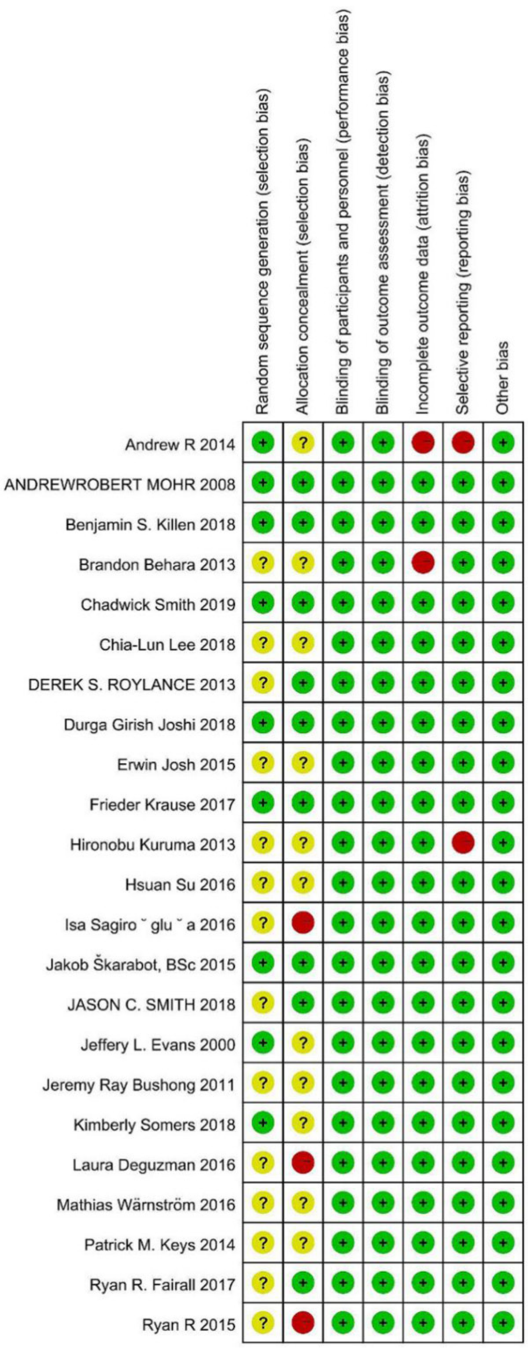

Figure 2. Quality assessment of studies included.

0.35). In contrast, significant differences existed between the two groups when comparing hip flexion (MD=-4.78 [-5.67, -3.88], P<0.0001), GH IR (MD=-4.74 [-7.03, -2.45], P=P<0.0001), Modified Thomas degree (MD=4.50 [0.99, 8.01], P=0.01), and last data (MD=-2.86 [-10.84, 5.12], P=0.48). There were significant differences between the tested subgroups (MD=-1.74 [-3.13, -0.35], P<0.0001) (**Figure 7**).

Sit to reach and other distance changes: Concerning distance of motion, sit to reach scores showed no significant differences between the two groups (MD=0.40 [-0.39, 1.18], P=0.32). Moreover, there were no significant differences between the tested subgroups (MD=0.04 [-0.32, 0.40], P=0.53) (**Figure 8**).

Publication bias

Figure 9 shows a funnel plot of studies included in the present meta-analysis concerning changes in the range of motion. All studies lied inside the 95% CIs, with an asymmetry distribution around the vertical, indicating obvious publication bias.

Discussion

Only 3 of the eight articles of relative distance investigated hip training. Two reported back-muscle training. However, the rest of the studies investigated lower limb muscle stretching, which reduced the sensitivity of the sit and reach tests. Range of motion of the joints was affected by its inherent structure and by the soft tissues. Movement of joints was related to the flexibility of soft tissues. Therapeutic methods that target the surrounding joint muscles were included in therapeutic strategies, aiming to induce changes in flexibility. Numerous studies reported that SS exercise weakens strength, power, sprinting, and agility performance [10, 18]. This study generally attributed stretching-induced muscular performance impairment to two main factors [29]: 1) Mechanical factors, such as decreased muscle stiffness, which may affect the length-tension relationship; and 2) Neural factors, which alter motor control strategies and reflex sensitivity. Herda [29] and Nelson [30] suggested that the stretching-induced force deficit could be more likely related to mechanical factors rather than to neural mechanisms.

Portillo-Soto [31] observed a significant increase in local skin temperature after treatment of calf muscles with Massage and Graston Technology. This suggests an increase in blood flow to the area of treatment. Therefore, SAFR might result in a more exceptional global dynamic activity than SS. This could contribute to the excitation of the CNS, counteracting any inhibition that might occur from rolling. In addition, the liquefaction degree of the fluid be-

Study or Subgroup	MFR Mean	MFR SD	MFR Total	MS Mean	MS SD	MS Total	Weight	Mean Difference IV, Fixed, 95% CI
DEREK S. ROYLANCE 2013	0.81	1.21	27	1.17	1.21	27	31.0%	-0.36 [-1.01, 0.29]
Durga Girish Joshi 2018	2.7	6.55	20	2.6	7.75	19	0.6%	0.10 [-4.41, 4.61]
Hsuan Su 2016	3.88	3.77	30	1.99	2.3	30	5.2%	1.89 [0.31, 3.47]
Isa Sagiro ˘ glu ˘ a 2016	0.97	1.04	16	0.34	1.17	16	21.9%	0.63 [-0.14, 1.40]
JASON C. SMITH 2018	7	5.7	29	7.3	10	29	0.7%	-0.30 [-4.49, 3.89]
Jeremy Ray Bushong 2011	3.18	4.83	19	2.98	4.53	19	1.5%	0.20 [-2.78, 3.18]
Kimberly Somers 2018	0.48	0.77	14	0.7	0.79	14	38.6%	-0.22 [-0.80, 0.36]
Patrick M. Keys 2014	2.4	5.36	10	2.53	6.47	10	0.5%	-0.13 [-5.34, 5.08]
Total (95% CI)			**165**			**164**	**100.0%**	**0.04 [-0.32, 0.40]**

Heterogeneity: Chi² = 9.83, df = 7 (P = 0.20); I² = 29%
Test for overall effect: Z = 0.22 (P = 0.83)

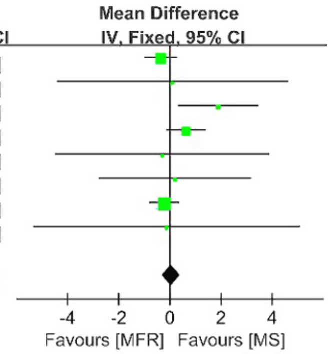

Figure 3. Forest plot and meta-analysis of the change of distance. MFR = myofascial release; MS = muscle stretch; SD = standard deviation; IV = inverse variance method; CI = confidence interval.

Study or Subgroup	MFR Mean	MFR SD	MFR Total	MS Mean	MS SD	MS Total	Weight	Mean Difference IV, Random, 95% CI
Andrew R 2014	6.88	3.97	40	12.26	4.21	40	10.9%	-5.38 [-7.17, -3.59]
ANDREWROBERT MOHR 2008	4.39	12.24	10	7.41	11.57	10	1.2%	-3.02 [-13.46, 7.42]
Benjamin S. Killen 2018	4.2	20.69	23	8.8	21.069	23	1.0%	-4.60 [-16.67, 7.47]
Brandon Behara 2013	14.75	19	14	17.6	18.58	14	0.7%	-2.85 [-16.77, 11.07]
Chadwick Smith 2019	1.4	3.54	17	1.3	3.39	16	9.3%	0.10 [-2.26, 2.46]
Chia-Lun Lee 2018	0.75	4.91	30	2.58	3.69	30	9.8%	-1.83 [-4.03, 0.37]
Durga Girish Joshi 2018	9	9.75	20	6.1	10.11	19	3.0%	2.90 [-3.34, 9.14]
Erwin Josh 2015	8.9	22.5	5	3.5	19.78	5	0.2%	5.40 [-20.86, 31.66]
Frieder Krause 2017	4.3	9.12	16	6.7	9.28	16	2.9%	-2.40 [-8.78, 3.98]
Hironobu Kuruma 2013	3.6	1.8	40	3.2	1.05	40	13.7%	0.40 [-0.25, 1.05]
Hsuan Su 2016	11.17	7.22	30	6.67	6.63	30	6.5%	4.50 [0.99, 8.01]
Jakob Škarabot, BSc 2015	0.4	0.67	11	0.9	0.67	11	13.9%	-0.50 [-1.06, 0.06]
Jeffery L. Evans 2000	3.02	3.19	5	5.88	8.53	5	2.0%	-2.86 [-10.84, 5.12]
Laura Deguzman 2016	7.1	4.7	35	9.1	4.4	35	9.9%	-2.00 [-4.13, 0.13]
Mathias Wärnström 2016	3.3	8.66	8	3.4	10.14	8	1.6%	-0.10 [-9.34, 9.14]
Ryan R 2015	3.84	1.41	12	8.58	4.49	12	8.5%	-4.74 [-7.40, -2.08]
Ryan R. Fairall 2017	3.84	5	12	8.58	6.14	12	4.9%	-4.74 [-9.22, -0.26]
Total (95% CI)			**328**			**326**	**100.0%**	**-1.44 [-2.66, -0.22]**

Heterogeneity: Tau² = 2.72; Chi² = 63.19, df = 16 (P < 0.00001); I² = 75%
Test for overall effect: Z = 2.31 (P = 0.02)

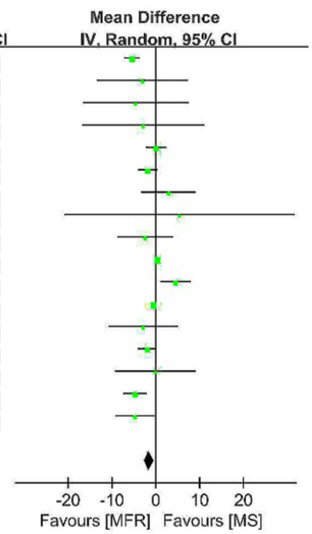

Figure 4. Forest plot and meta-analysis of the change of range of motion. MFR = myofascial release; MS = muscle stretch; SD = standard deviation; IV = inverse variance method; CI = confidence interval.

Study or Subgroup	MFR Mean	MFR SD	MFR Total	MS Mean	MS SD	MS Total	Weight	Mean Difference IV, Fixed, 95% CI
Benjamin S. Killen 2018	2.17	95.69	23	-11.84	92.85	23	0.0%	14.01 [-40.48, 68.50]
Chia-Lun Lee 2018	0.09	0.19	30	-0.02	0.22	30	54.4%	0.11 [0.01, 0.21]
Hsuan Su 2016	0.17	0.28	30	0	0.15	30	45.6%	0.17 [0.06, 0.28]
Jeffery L. Evans 2000	0	11.8	5	0.9	9.34	5	0.0%	-0.90 [-14.09, 12.29]
Ryan R 2015	-4.54	5.77	12	-1.27	13.84	12	0.0%	-3.27 [-11.75, 5.21]
Total (95% CI)			**100**			**100**	**100.0%**	**0.14 [0.06, 0.21]**

Heterogeneity: Chi² = 1.47, df = 4 (P = 0.83); I² = 0%
Test for overall effect: Z = 3.50 (P = 0.0005)

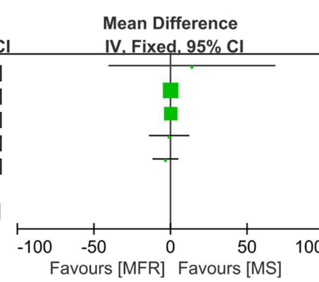

Figure 5. Forest plot and meta-analysis of the change of strength. MFR = myofascial release; MS = muscle stretch; SD = standard deviation; IV = inverse variance method; CI = confidence interval.

tween the fascia in this area needs to be strengthened, while the force of friction needs to be reduced, enhancing the force. After the release of fascia, muscle tension around the joint would be more balanced, the joint would be placed in a better position, and the biomechanical effects of force would be improved. Finally, when the fascia is released, embedded nerves become more conductive. Nerve impulses become more abundant and the muscle

Study or Subgroup	MFR Mean	MFR SD	MFR Total	MS Mean	MS SD	MS Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
Isa Sagiro ˘ glu ˘ a 2016	-2.08	1.79	16	-2.01	1.7	16	66.7%	-0.04 [-0.73, 0.65]
Mathias Wärnström 2016	-0.2	19.12	8	-0.2	17.65	8	33.3%	0.00 [-0.98, 0.98]
Total (95% CI)			**24**			**24**	**100.0%**	**-0.03 [-0.59, 0.54]**
Heterogeneity: Chi² = 0.00, df = 1 (P = 0.95); I² = 0%								
Test for overall effect: Z = 0.09 (P = 0.93)								

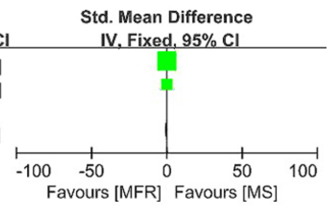

Figure 6. Forest plot and meta-analysis of the change of jump levels. MFR = myofascial release; MS = muscle stretch; SD = standard deviation; IV = inverse variance method; CI = confidence interval.

Study or Subgroup	MFR Mean	MFR SD	MFR Total	MS Mean	MS SD	MS Total	Weight	Mean Difference IV, Random, 95% CI
5.1.1 knee fle								
Chia-Lun Lee 2018	0.75	4.91	30	2.58	3.69	30	8.6%	-1.83 [-4.03, 0.37]
Frieder Krause 2017	4.3	9.12	16	6.7	9.28	16	3.3%	-2.40 [-8.78, 3.98]
Hironobu Kuruma 2013	3.6	1.8	40	3.2	1.05	40	10.7%	0.40 [-0.25, 1.05]
Subtotal (95% CI)			**86**			**86**	**22.7%**	**-0.55 [-2.40, 1.29]**
Heterogeneity: Tau² = 1.39; Chi² = 4.28, df = 2 (P = 0.12); I² = 53%								
Test for overall effect: Z = 0.59 (P = 0.56)								
5.1.2 knee ext								
Durga Girish Joshi 2018	9	9.75	20	6.1	10.11	19	3.4%	2.90 [-3.34, 9.14]
Laura Deguzman 2016	7.1	4.7	35	9.1	4.4	35	8.7%	-2.00 [-4.13, 0.13]
Mathias Wärnström 2016	3.3	8.66	8	3.4	10.14	8	1.9%	-0.10 [-9.34, 9.14]
Subtotal (95% CI)			**63**			**62**	**14.0%**	**-1.17 [-3.62, 1.28]**
Heterogeneity: Tau² = 0.80; Chi² = 2.20, df = 2 (P = 0.33); I² = 9%								
Test for overall effect: Z = 0.93 (P = 0.35)								
5.1.3 ankle joint								
Chadwick Smith 2019	1.4	3.54	17	1.3	3.39	16	8.3%	0.10 [-2.26, 2.46]
Erwin Josh 2015	8.9	22.5	5	3.5	19.78	5	0.3%	5.40 [-20.86, 31.66]
Jakob Škarabot, BSc 2015	0.4	0.67	11	0.9	0.67	11	10.8%	-0.50 [-1.06, 0.06]
Subtotal (95% CI)			**33**			**32**	**19.4%**	**-0.47 [-1.01, 0.08]**
Heterogeneity: Tau² = 0.00; Chi² = 0.43, df = 2 (P = 0.81); I² = 0%								
Test for overall effect: Z = 1.68 (P = 0.09)								
5.1.4 hip fle								
Andrew R 2014	6.88	3.97	40	12.26	4.21	40	9.3%	-5.38 [-7.17, -3.59]
ANDREWROBERT MOHR 2008	4.39	12.24	10	7.41	11.57	10	1.5%	-3.02 [-13.46, 7.42]
Benjamin S. Killen 2018	4.2	1.79	23	8.8	1.82	23	10.4%	-4.60 [-5.64, -3.56]
Brandon Behara 2013	14.75	19	14	17.6	18.58	14	0.9%	-2.85 [-16.77, 11.07]
Subtotal (95% CI)			**87**			**87**	**22.1%**	**-4.78 [-5.67, -3.88]**
Heterogeneity: Tau² = 0.00; Chi² = 0.73, df = 3 (P = 0.87); I² = 0%								
Test for overall effect: Z = 10.44 (P < 0.00001)								
5.1.5 gh IR								
Ryan R 2015	3.84	1.41	12	8.58	4.49	12	7.8%	-4.74 [-7.40, -2.08]
Ryan R. Fairall 2017	3.84	5	12	8.58	6.14	12	5.1%	-4.74 [-9.22, -0.26]
Subtotal (95% CI)			**24**			**24**	**13.0%**	**-4.74 [-7.03, -2.45]**
Heterogeneity: Tau² = 0.00; Chi² = 0.00, df = 1 (P = 1.00); I² = 0%								
Test for overall effect: Z = 4.06 (P < 0.0001)								
5.1.6 Modified Thomas degree								
Hsuan Su 2016	11.17	7.22	30	6.67	6.63	30	6.5%	4.50 [0.99, 8.01]
Subtotal (95% CI)			**30**			**30**	**6.5%**	**4.50 [0.99, 8.01]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 2.51 (P = 0.01)								
5.1.7 unknow joint								
Jeffery L. Evans 2000	3.02	3.19	5	5.88	8.53	5	2.4%	-2.86 [-10.84, 5.12]
Subtotal (95% CI)			**5**			**5**	**2.4%**	**-2.86 [-10.84, 5.12]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.70 (P = 0.48)								
Total (95% CI)			**328**			**326**	**100.0%**	**-1.74 [-3.13, -0.35]**
Heterogeneity: Tau² = 4.56; Chi² = 114.06, df = 16 (P < 0.00001); I² = 86%								
Test for overall effect: Z = 2.46 (P = 0.01)								
Test for subgroup differences: Chi² = 85.15, df = 6 (P < 0.00001), I² = 93.0%								

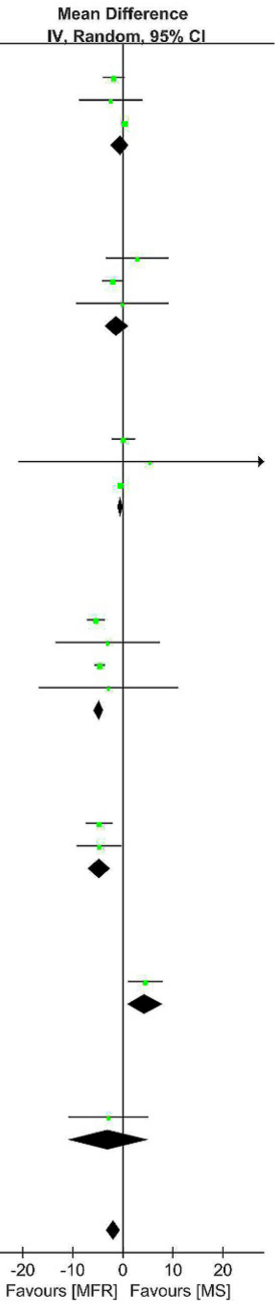

Figure 7. Forest plot and sub-analysis of range of motion changes. MFR = myofascial release; MS = muscle stretch; SD = standard deviation; IV = inverse variance method; CI = confidence interval.

Study or Subgroup	MFR Mean	MFR SD	MFR Total	MS Mean	MS SD	MS Total	Weight	Mean Difference IV, Fixed, 95% CI
6.1.1 sit to reach								
DEREK S. ROYLANCE 2013	0.81	1.21	27	1.17	1.21	27	31.0%	-0.36 [-1.01, 0.29]
Durga Girish Joshi 2018	2.7	6.55	20	2.6	7.75	19	0.6%	0.10 [-4.41, 4.61]
Hsuan Su 2016	3.88	3.77	30	1.99	2.3	30	5.2%	1.89 [0.31, 3.47]
Isa Sagiro ˇ glu ˇ a 2016	0.97	1.04	16	0.34	1.17	16	21.9%	0.63 [-0.14, 1.40]
JASON C. SMITH 2018	7	5.7	29	7.3	10	29	0.7%	-0.30 [-4.49, 3.89]
Jeremy Ray Bushong 2011	3.18	4.83	19	2.98	4.53	19	1.5%	0.20 [-2.78, 3.18]
Subtotal (95% CI)			**141**			**140**	**60.9%**	**0.21 [-0.25, 0.67]**
Heterogeneity: Chi² = 8.55, df = 5 (P = 0.13); I² = 42%								
Test for overall effect: Z = 0.88 (P = 0.38)								
6.1.2 knee to wall								
Kimberly Somers 2018	0.48	0.77	14	0.7	0.79	14	38.6%	-0.22 [-0.80, 0.36]
Subtotal (95% CI)			**14**			**14**	**38.6%**	**-0.22 [-0.80, 0.36]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.75 (P = 0.46)								
6.1.3 hamstring distance								
Patrick M. Keys 2014	2.4	5.36	10	2.53	6.47	10	0.5%	-0.13 [-5.34, 5.08]
Subtotal (95% CI)			**10**			**10**	**0.5%**	**-0.13 [-5.34, 5.08]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 0.05 (P = 0.96)								
Total (95% CI)			**165**			**164**	**100.0%**	**0.04 [-0.32, 0.40]**
Heterogeneity: Chi² = 9.83, df = 7 (P = 0.20); I² = 29%								
Test for overall effect: Z = 0.22 (P = 0.83)								
Test for subgroup differences: Chi² = 1.28, df = 2 (P = 0.53), I² = 0%								

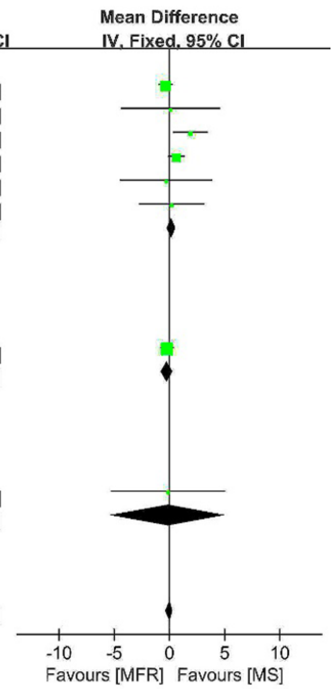

Figure 8. Forest plot and sub-analysis of distance changes. MFR = myofascial release; MS = muscle stretch; SD = standard deviation; IV = inverse variance method; CI = confidence interval.

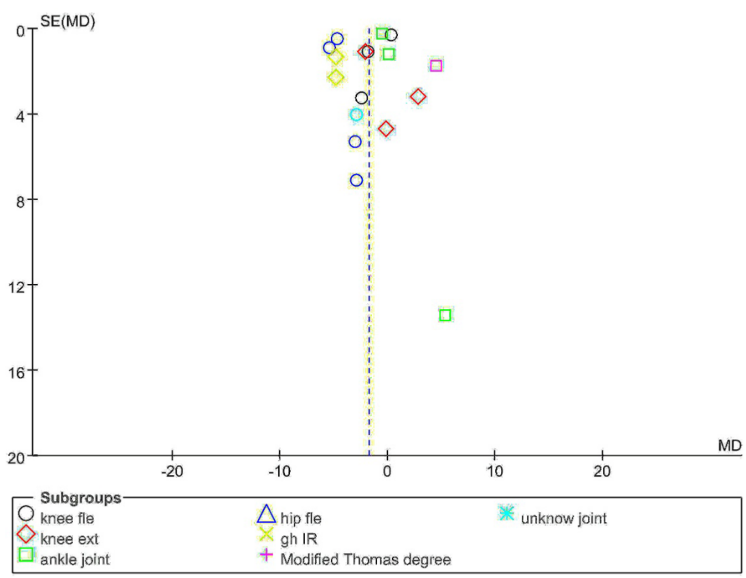

Figure 9. Funnel plots illustrating meta-analysis of range of motion changes. SE = standard error; OR = odds ratio.

fibers are recruited. This ultimately leads to greater contractile strength.

Dynamic and static stretching: Mohammad Taghi Amiri-Khorasani [32] showed that dynamic stretching was significantly better than all other stretching protocols in DROM and SROM (P<0.05). This could be related to the fact that dynamic stretching of the hip flexor can enhance muscle strength, activity, and stiffness due to a higher post-activation potential (PAP). In contrast, static stretching of the hip extensor may lead to a decline in muscle strength and stiffness. Therefore, DFSE might be the best stretching approach for inducing post-activation potential in the muscles and for reducing stiffness.

MFR: Self-myofascial release and the foam roller belong to compression muscle fascia release [33]. Justin Stanek showed that compression myofascial release increased ankle DF in participants with ankle DF ROM deficits after a single treatment. Therefore, clinicians should consider adding CMR as a treatment intervention for patients with DF deficits.

Further study: Muscle fascia adhesion induces muscle pain. Facial adhesion can narrow the range of motion of the joints and reduce its elasticity, or even shorten it. It may stretch the muscles in adjacent areas, which would contract excessively, resulting in excessive strain. The solution to the problem is the gentle release of the fascia in the area of adhesion. In fact, the whole process would take only few minutes. However, few articles have investigated pain in both methods. Therefore, more studies are required, further investigating the effects of combining both methods for pain relief.

In the process of reading the articles, seven of the included studies investigated the effects of combined FR and SS treatment. More articles examining the combination of FR and SS are necessary in the future.

Conclusion

The current meta-analysis of 23 RCTs, including 884 patients, compared the efficacy of FMR and MS. Results suggest that MS is more effective than FMR, wherein the range of motion is more significantly improved in MS-treated patients. There were no significant differences in distance changes. Moreover, MFR can better improve muscle strength, compared with MS. Comparing movement jump levels, there were no significant differences. Despite a rigorous approach, inherent limitations of inclusion make it impossible to come to a clear conclusion. To confirm and update the findings of this meta-analysis in the future, large-scale and well-designed randomized controlled trials, with extensive follow-ups, are needed.

Disclosure of conflict of interest

None.

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