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Review

Effects of Self-myofascial Release Instruments on Performance and Recovery: An Umbrella Review

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ABSTRACT

International Journal of Exercise Science 15(3): 861-883, 2022. Introduction: Currently, the use of self-myofascial release (SMR) instruments is not uncommon in our society, especially in sports. The most common SMR instruments are foam rollers, roller massagers, and balls. Regardless of the instrument used, the main objectives are to enhance performance and recovery. Nevertheless, many studies point out that there is still a lack of robust scientific evidence documenting the exact mechanisms that explain its true effects, therefore some authors affirm that the reported benefits are anecdotal in nature. Objective: This overview aims to summarize, from systematic reviews, the effectiveness of SMR instruments on performance and recovery. Material and Methods: This study followed the PRISMA principles. Systematic reviews were found on the electronic databases according to an established P (healthy active individuals) I (SMR using instruments) C (other treatment, placebo, sham, or no treatment) O (performance and recovery) S (systematic reviews) search strategy. Additionally, methodological analysis was performed using R-AMSTAR. Results: Initially, it was found 15 systematic reviews. However, after methodological analysis, only 7 systematic reviews had sufficient quality to be included. From those, it was found that SMR using instruments is beneficial to enhancing short-term flexibility-related and recovery-related outcomes. Inconstant data was reported in muscular-related outcomes. Nevertheless, beyond pain during SMR, no major adverse effects were found. Different effects between time, pressure and other instrument characteristics were also found. Conclusion: SMR using instruments can be a safe intervention used in sports to enhance performance and recovery from previous training/competition or between matches.

KEY WORDS: Self-myofascial release instruments; performance; recovery

INTRODUCTION

During the past two decades, active self-massage treatments using instruments of various densities, materials, shapes and sizes (such as, foam rollers, roller massagers, sticks or balls) have rapidly gained popularity amongst elite and recreational athletes (13, 41, 54, 97). These instruments are affordable, time-efficient, simple to use and easy to access. Regarding self-myofascial release (SMR), the main benefit attributed in the literature is enhanced performance and recovery, without decreasing athletic parameters or having major contraindications or adverse effects (6, 8, 13, 17, 25, 84, 87, 96). Self-myofascial release is achieved either by using bodyweight to apply pressure to the soft tissues (e.g., foam rollers), or by applying pressure in target muscles via utilizing upper body strength (e.g., roller massagers) (13, 37). The motions by both direct and sweeping pressure on the soft tissues, stretch them and generate friction between the tissues and the instrument (74). Nevertheless, many studies point out that there is still a lack of robust scientific evidence documenting the exact mechanism (or mechanisms) that explains its true effects (6, 8, 22, 37, 84). The main reasons are (6, 22): myofascial research is still in its infancy; there is no clearance on the duration of treatments and breaks; there is no agreement on the type of roller to be used; there is no clear direction on the force to be applied on the tissue; the speed and frequency of rolling may vary from study-to-study; and the treatment frequency that should be repeated in one session are not always the same. So, due these uncertainties and discrepancies on the treatment methods/protocols and therapeutic effects, some authors affirm that the reported benefits are anecdotal in nature, making evidence-based practice difficult (22). Additionally, to our knowledge, there is no available umbrella review on the effectiveness of SMR instruments on performance and recovery. Therefore, the aim of this overview is to summarize, from systematic reviews, the effectiveness of SMR instruments on performance and recovery.

METHODS

In an attempt to ensure a high-quality study, this overview was conducted following the PRISMA (*P*referred *R*eporting *I*tems for *S*ystematic reviews and *M*eta-*A*nalyses) principles (56). Additionally, this research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (68).

Search Strategy

The literature search aimed to identify systematic reviews that evaluated the effects of SMR instruments in performance and recovery. Instrumental SMR was operationally defined as an active self-massage technique involving a repetitive rolling action over a muscle group using any type of massage tool. In January 2021, systematic and comprehensive searches were conducted in the following electronic databases: MEDLINE, Embase, Physiotherapy Evidence Database, The Cochrane Library, EBSCOhost, SciELo, Science Direct, Google Scholar, Research Gate and B-ON.

The studies selection respected the following terms to guide the search strategy using the PICOS (Patients, Intervention, Comparison, Outcomes, Studies) model (Figure 1):

P	Healthy active individuals
I	Active self-myofascial release using instruments
C	Any other treatment, placebo, sham, or no treatment
O	Performance and recovery
S	Systematic reviews

Figure 1. Description of the terms used to guide search strategy using the PICO model;
P – Patients; I – Intervention; C – Comparison; O – Outcomes; S – Studies

For the search strategy a conjunction of keywords, mesh terms and established search filters were used. The main keywords used to search in the databases were: "Self-myofascial release"; "Foam roller"; "roller massager". The terms (and their associates/derivatives) were then combined with the appropriate truncation and boolean connectors. These terms were translated and searched in Portuguese, Spanish, French and English. They were identified after preliminary literature searches and by crosschecking them against previous relevant systematic reviews. An example of an online search strategy draft used in MEDLINE database is presented in Figure 2:

1. "Systematic review"[Title] OR "Systematic literature review"[Title] OR "Systematic scoping review"[Title] OR "Systematic narrative review"[Title] OR "Systematic qualitative review"[Title] OR "Systematic evidence review"[Title] OR "Systematic quantitative review"[Title] OR "Systematic meta-review"[Title] OR "Systematic critical review"[Title] OR "Systematic mixed studies review"[Title] OR "Systematic mapping review"[Title] OR "Systematic cochrane review"[Title] OR "Systematic search and review"[Title] OR "Systematic integrative review"[Title]
2. "Systematic review"[Publication Type]
3. 1 OR 2
4. "2000/01/01"[Date - Publication] : "2020/12/31"[Date - Publication]
5. "Humans"[MeSH Terms]
6. English[Language]
7. 3 AND 4 AND 5 AND 6
8. "Self"[All Fields] OR "Myofascial"[All Fields] OR "Self Myofascial"[All Fields] OR "Self-Myofascial"[All Fields] OR "SMR"[All Fields] OR "Self massag*"[All Fields] OR "Self-massag*"[All Fields] OR "Roll*"[All Fields] OR "Foam roll*"[All Fields] OR "Roll* massage*"[All Fields] OR "Massag* roll*"[All Fields] OR "Sick*"[All Fields] OR "Massag* sick*"[All Fields] OR "Massag* ball*"[All Fields]
9. "Sport*"[All Fields] OR "Athlet*"[All Fields] OR "Activ*"[All Fields] OR "Health*"[All Fields] OR "Asymptomatic"[All Fields]
10. "Perform*"[All Fields] OR "Muscul*"[All Fields] OR "Muscul* activat*"[All Fields] OR "Strength*"[All Fields] OR "Force"[All Fields] OR "Power"[All Fields] OR "Peak torque*"[All Fields] OR "Iso*"[All Fields] OR "Concentric*"[All Fields] OR "Eccentric*"[All Fields] OR "Plyometric*"[All Fields] OR "Ballistic*"[All Fields] OR "Jump*"[All Fields] OR "Speed*"[All Fields] OR "Velocit*"[All Fields] OR "Run*"[All Fields] OR "Enduranc*"[All Fields] OR "Agilit*"[All Fields] OR "Reaction*"[All Fields] OR "Balanc*"[All Fields] OR "Accelerat*"[All Fields] OR "Flexibilit*"[All Fields] OR "Range of mo*"[All Fields] OR "ROM"[All Fields] OR "Temperature"[All Fields] OR "Blood"[All Fields] OR "VO2"[All Fields] OR "Oxygen uptake"[All Fields]
11. "Delayed onset of muscle soreness"[All Fields] OR "DOMS"[All Fields] OR "Exercise-induced muscle damage"[All Fields] OR "EIMD"[All Fields] OR "Fatigue"[All Fields] OR "Recover*"[All Fields] OR "Lact*"[All Fields]
12. 9 OR 10 OR 11
13. 7 AND 8 AND 12

Figure 2. Description of the online search strategy

Additional publications that were not found during the original database search were identified through manual searches at the related articles and reviews reference lists.

Study Selection Process

The reviewers independently screened the titles and abstracts yielded by the search against the inclusion and exclusion criteria and performed the selection of the potential studies. The full versions of the systematic reviews that appeared to meet the inclusion criteria were obtained. When there was any uncertainty or insufficient data presented, the study's authors were contacted, via email, in order to gather the missing components. Duplicates and any systematic review that was obviously outside the scope of the review were removed. In case of study selection disparities, the reviewers reached an agreement through verbal discussion or arbitration. The inclusion and exclusion criteria applied to this review are described in Table 1.

Table 1. Inclusion and exclusion criteria

Inclusion The studies must:	**Exclusion** The studies cannot:
have at least one of the keywords;	
be systematic reviews (with or without meta-analysis), prior to January 2021, that evaluate the effects of SMR instruments as primary objective;	be books, randomized controlled trials, case reports, expert opinions, conference papers, academic thesis, literature reviews or narrative reviews;
be published in peer-review journals;	
have experimental or control groups with detailed description of the protocols and the SMR instruments used;	include studies with myofascial release performed by therapists using instruments or manual therapy;
include asymptomatic, healthy physical active individuals or athletes;	include sedentary, injured, unhealthy, chronic or acute ill participants;
measure acute and/or chronic performance and/or recovery related outcomes;	include experimental or control group composed by any kind of animal;
have their full version, in English, Portuguese, Spanish or French.	be written in other languages.

Data Extraction and Syntheses

The data that was extracted from the selected publications to assess the effects of SMR instruments included: title, authors' name, year of publication, SMR instruments used, participants' sample size and their characteristics, objectives, description of the interventions, description of the control groups, studies' outcomes, assessment times, studies' results and studies' conclusions.

Outcomes

Considering the broad scope of performance and recovery related outcomes, it was decided to restrict the work to specific umbrella terms (Figure 3):

Primary Outcomes	**Secondary Outcomes**
1. Muscular Activation, Strength, Power 2. Speed, Endurance, Oxygen Uptake 3. Agility, Reaction, Balance 4. Flexibility, Range of Motion 5. Blood and Lymphatic Flow 6. Biomarkers of Fatigue, Recovery, Exercise-Induced Muscle Damage, Delayed Onset Muscle Soreness	1. Adverse effects in SMR using instruments

Figure 3. Primary and secondary outcomes

Quality Assessment

The authors independently scored the bias of the studies by using the R-AMSTAR (Revised A MeaSurement Tool to Assess systematic Reviews) 11-item questionnaire (44). In R-AMSTAR, each domain's score ranges between 1 (minimum) and 4 (maximum), which means the total scores have a range of 11 (minimum) to 44 (maximum) (44). Therefore, the overall score can be translated into a quality grade, such as: A (high quality: 33-44), B (moderate quality: 23-32), C (low quality: 13-22) and D (very low quality: 11-12) (44). Following the recommendations that only ratings of 23/44 on the R-AMSTAR total score have at least moderate methodological quality, that was established as the criteria to include a systematic review in this overview (44).

RESULTS

Selection of the studies

A set of 33 records were identified via searching databases. After the application of the inclusion and exclusion criteria, 15 articles have emerged (2, 6, 7, 13, 21, 22, 33, 37, 46, 64, 79, 84, 87, 96, 97). A diagram (see Figure 4) summarizes the selection process.

Methodological Quality

After the selection of the studies, the reviewers independently applied the R-AMSTAR to evaluate the methodological quality of the 15 selected papers (2, 6, 7, 13, 21, 22, 33, 37, 46, 64, 79, 84, 87, 96, 97). After this process, they reached an agreement through verbal discussion or arbitration. The methodological quality assessment using the R-AMSTAR revealed a mean score of 22.3 (range 16 – 28). At the end, 8 of the systematic reviews (2, 6, 7, 21, 22, 46, 64, 84) were excluded because they did not reach 23/44, raising the mean score to 25.3. The classifications obtained are described in the Table 2.

Study Characteristics

Overall, the 7 included systematic reviews (13, 33, 37, 79, 87, 96, 97) were published from 2015 (13) to 2020 (87, 97) and conducted in Africa (South Africa (33)), Europe (England (87) and

Germany (96, 97)), North America (Canada (37) and United States of America (13)), and South America (Brazil (79)). The number of studies included in the systematic reviews were 168 (maximum = 49 (33); minimum = 4 (79)), with a total of 3167 subjects (maximum = 757 (87); minimum = 55 (79)). However, after excluding duplicates, from 78 studies the real number of participants were 1989. The included studies were conducted between 2002 and 2019.

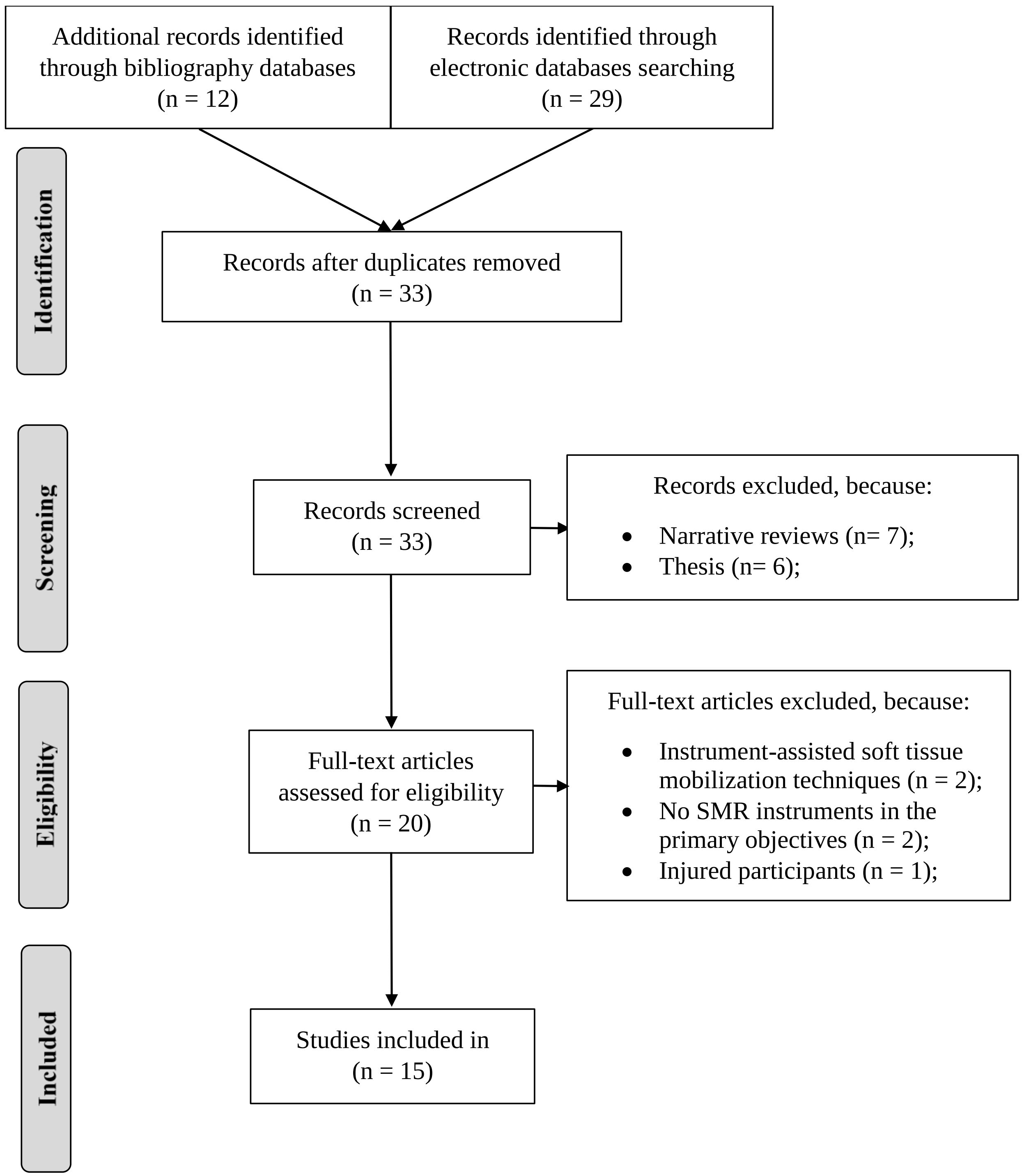

Figure 4. Results of the inclusion and exclusion criteria.

Table 2. Methodological quality of eligible studies (*n* = 15)

Study (A to Z; Year)	R-AMSTAR Items 1	2	3	4	5	6	7	8	9	10	11	**R-AMSTAR Score** (11–44)	**Grade** (A–D)
Anderson et al. (2)	3	1	2	2	1	4	2	1	1	1	1	19	C
Beardsley and Škarabot (6)	2	1	4	2	1	4	3	1	1	1	2	22	C
Behm et al. (7)	3	2	4	1	2	4	1	1	2	1	1	22	C
Cheatham et al. (13)	3	4	2	2	3	4	3	2	1	1	1	26	B
DeBruyne et al. (21)	3	1	3	3	1	4	2	1	1	1	1	21	C
Dębski et al. (22)	3	1	2	2	1	1	1	1	1	1	2	16	C
Hendricks et al. (33)	3	2	3	2	2	4	2	1	1	1	2	23	B
Hughes and Ramer (37)	4	2	3	2	2	4	2	1	1	1	2	24	B
Lavandero et al. (46)	3	1	2	2	2	4	1	1	1	1	1	19	C
Moraleda et al. (64)	2	1	3	2	2	4	2	1	1	1	1	20	C
Righi et al. (79)	2	4	3	3	2	4	1	1	1	1	1	23	B
Schroeder and Best (84)	1	1	3	1	2	3	1	1	1	1	3	18	C
Skinner et al. (87)	2	4	4	2	2	4	3	1	3	1	2	28	B
Wiewelhove et al. (96)	2	3	3	2	2	4	3	2	3	1	2	27	B
Wilke et al. (97)	3	2	4	2	2	4	3	1	1	2	3	27	B
Average	2.6	2	3	2	1.8	3.7	2	1.1	1.3	1.1	1.7	22.3	C

R-AMSTAR items: 1 – Was an ''a priori'' design provided?; 2 – Was a comprehensive literature search performed?; 3 – Was the status of publication used as an inclusion criterion?; 4 – Was a list of studies provided?; 5 – Were the characteristics of the included studies provided?; 6 – Was the scientific quality of the included studies assessed and documented?; 7 – Was the scientific quality of the included studies used appropriately in formulating conclusions?; 8 – Were the methods used to combine the findings of studies appropriate?; 9 – Was the likelihood of publication bias assessed?; 10 – Was the conflict of interest included?; 11 – Was the conflict of interest included?

Table 3 provides a summary of the included systematic reviews characteristics.

Table 3. Systematic reviews summaries (*n* = 7)

Authors (A to Z; year)	**Objectives**	**N° of included studies (subjects)**	**Results/Conclusions**
Cheatman et al. (13)	To know if SMR instruments improve joint range of motion, enhance recovery/reduce DOMS and have effects on muscle performance.	14 (*n* = 260)	*Performance* • Both the FR and the RM may offer short-term benefits for increasing sit and reach scores and joint ROM at the hip, knee, and ankle without enhance or negatively affecting muscle performance. SMR using a foam roll for 30 sec – 1 min (2 to 5 sessions) or roller massager for 5 sec – 2 min (2 to 5 sessions) may be beneficial for enhancing joint flexibility as a pre-exercise warm-up and cool down due to its short-term

			benefits. Also, SMR may have better effects when combined with SS after exercise. *Recovery* • FR and RM after high intensity exercise, do attenuate decreases in lower extremity muscles and reduce perceived pain in subjects with a post exercise intervention period ranging from 10 – 20 min. Continued FR (20 min per day) over 3 days may further decrease pain level and using a RM for 10 min may reduce pain up to 30 min.
Hendricks et al. (33)	To determine the effects of FR on performance and recovery.	49 (*n* = 644)	*Performance* • FR did not improve athletic performance. However, FR did not impede various force and power outcome measures. FR appears to be a good tool to use for or during a warm-up to increase flexibility, especially in combination with DS and active warm-up. Furthermore, it appears that FR could be a substitute for SS. So, FR should be used to enhance performance in activities or sports that require flexibility (namely, in the hip, knee and ankle joints). *Recovery* • FR seems beneficial for recovery from EIMD, DOMS and its physical performance decreases. Also, FR may be beneficial for athletes to recover and return to their normal performance faster. Neural and vascular responses, may be the main mechanisms responsible by the enhance recovery. A slow undulating 30 – 60 sec of FR, 3 – 5 times (sets) with 10 – 30 sec rest periods between each set may be optimal for both performance and recovery.

Authors (A to Z; year)	**Objectives**	**N° of included studies (subjects)**	**Results/Conclusions**
Hughes and Ramer (37)	To determine the optimal duration using a FR or a RM for muscle pain, ROM, and athletic performance.	22 (*n* = 328)	*Performance* • SMR instruments did not enhance muscular related performance. Nevertheless, most of the studies reported statistically significant ROM improvements. When split by studies that tested ROM by active versus passive means, 5 of 9 studies measuring active ROM showed significant improvements while 5 of 8 studies measuring passive ROM studies noted the same. However, the testing techniques used in the studies to access ROM are to heterogeneous

			to directly compare results. There was a near equal split of positive and negative results when considering both the total roller session duration and the total time spent on one muscle. *Recovery* • Overall, results for the recovery from DOMS indicated that the use SMR instruments, for any duration, would improve a subject's short-term outcomes. FR a single muscle group for under 45 sec may be insufficient for adequate recovery from DOMS. More robust results were seen in studies that intervened for durations between 90 – 600 sec per muscle group, suggesting that a minimum dose of 90 sec is most reliable and is best suited for recovery/DOMS.
Righi et al. (79)	To identify the effects of FR and RM on pain and musculoskeletal function in healthy volunteers after exercise.	4 (*n* = 95)	*Performance* • FR increased the hip and knee ROM, in comparison to the control groups. Passive quadriceps ROM increased 48h and 72h after the protocol and the hamstrings increased only 72h after. Dynamic hamstring ROM increased 24h after. Mixed results were found regarding muscular-related outcomes. *Recovery* • SMR reduced the perception of pain and increased PPT when compared to the control group and the control limb.

Authors (A to Z; year)	**Objectives**	**N° of included studies (subjects)**	**Results/Conclusions**
Skinner et al. (87)	To know the effects of FR on ROM, laboratory/field-based athletic measures, and on recovery.	32 (*n* = 757)	*Performance* • FR had a large, positive effect upon ROM and muscular length immediately following application, compared to baseline measurements or control, and that the positive effects are elicited independently of the measurement method, the FR dosage application or the sex of the participants. Besides flexibility, mixed results were found in laboratory or field-based measures. Several inconsistencies were apparent in the application of the FR between studies, making direct comparison challenging. Nevertheless, findings suggest that multiple sets of application may be required to elicit an effect, as no beneficial response from a single set application was consistently reported.

			Recovery • All studies showed positive effects on EIMS/DOMS in comparison to control groups. Additionally, no studies identified any adverse or harmful effects from the application of FR.
Wiewelhove et al. (96)	To compare the effects of FR and RM applied before and after exercise on sprint, jump, and strength performance as well as on flexibility and muscle pain outcomes.	21 (*n* = 757)	*Performance* • Pre-rolling resulted in a small improvement in sprint performance and flexibility, whereas the effect on jump and strength performance was negligible. *Recovery* • Post-rolling slightly attenuated EIMD in sprint and strength performance. It also reduced muscle pain perception.
Wilke et al. (97)	To quantify the immediate effects of FR on ROM in healthy adults.	26 (*n* = 609)	*Performance* • Compared to no-exercise, FR had a large positive effect on ROM, but was not superior to stretching. Although the few individual study findings suggest that FR with vibration may be more effective than no-exercise or FR without vibration, the pooled results did not reveal significant differences. Most potential effect modifiers (e.g., BMI, speed or duration) do not have a significant impact, but FR may be less effective in men. The rolled muscle seems to represent a second relevant moderator. *Recovery* • Not reported

Abbreviations: *DOMS* – Delay onset muscular soreness; *EIMD* – Exercise-induced muscular damage; *FR* – Foam roller; *h* – Hours; *min* – Minute; *PPT* – Pressure pain threshold; *RM* – Roller massager; *ROM* – Range of motion; *sec* – Seconds; *SMR* – Self-myofascial release; *SS* – Static stretching

DISCUSSION

The discussion will be presented according to the main outcomes (performance and recovery), SMR physiological responses and adverse effects, and practical orientations.

Main outcomes

The two main umbrella outcomes found in the systematic reviews were performance and recovery-related.

Performance

Performance-related outcomes were explored in all systematic reviews (13, 33, 37, 79, 87, 96, 97). Although the data included in this review varied widely, a deeper analysis revealed a clear distinction between outcomes. Therefore, the outcomes will be divided in two sub-groups: flexibility-related and muscular-related.

Flexibility: As reported by the included systematic reviews, the results were consistent for the positive use of SMR instruments in order to increase flexibility, especially compared to placebo/sham intervention/no intervention (d = 0.74; 95% CI: 0.42 – 1.01) (97). Specifically, Skinner et al. (87) found a large, positive effect upon range of motion (ROM) immediately following application (d = 0.76; 95% CI: 0.55 – 0.98), and that the positive effects of foam rolling on ROM are elicited independently of the measurement method, the foam rolling dosage application or the sex of the participants. Furthermore, most of the studies focused in the lower body, in particular, knee and hip ROM. The SMR instruments operationalization can be the justification for the higher number of studies carried out in the lower limb. The SMR instruments used included roller massager, balls and, especially, foam rollers. As foam rollers are of reasonable size and need the person's bodyweight to properly perform it (13, 37), it is easier to use (movement control, balance, velocity and pressure) in the lower limb, such as in the gluts, hamstrings and quadriceps. In addition, although in limited number, there was evidence of increased shoulder (45) and ankle ROM (42), thoracolumbar mobility (28) and sit-and-reach test (9, 29, 39).

Compared to stretching, the importance of using SMR instruments varied, as the type of stretching changed. Generally, no difference between SMR and stretching (d = -0.02; 95% CI: -0.73 − 0.69) was found (97). In more detail, it seems that SMR instruments reached similar results as dynamic stretching and proprioceptive neuromuscular facilitation (PNF), but was not superior to static stretching. Even when SMR was added to static stretching, in most of the studies, the differences with static stretching alone were not statistically different (24, 66, 86, 88). So, for flexibility related-outcomes static stretching seems to be the most promising intervention. Parallel results were reached when SMR instruments were compared with dynamic warm-ups. SMR was not superior to dynamic warm-ups alone or when SMR was added to a warm-up protocol (4, 65, 73).

Other SMR-related factors were hypothesized to influence the results, such as rolled site, time and velocity, pressure applied, SMR instrument used, and the way to perform it. It seems that rolling in the mediolateral axis is more effective in increasing sit-and-reach in comparison to the anteroposterior axis (72). Similar results were found when rolling in the muscles was compared with rolling in the fascia, where the ROM improvement was superior in the muscular group (30). These differences may be explained by the SMR physiological effects and the biomechanical importance for the tests performed. Other explanation may be the time in the rolling session. Consistent results were found for the need to do more rolling time in order to achieve more positive flexibility-related outcomes (10, 60, 75, 92). In fact, the Hendricks et al. (33) systematic review pinpointed the 90 - 120 seconds range, as the most beneficial to enhance flexibility-related outcomes. However, it needs to be noted that, regardless of the rolling time, the effects of the rolling session are lost as the time passes (39, 86). These findings may be transversal for other SMR techniques, other than the usual foam rollers (i.e., balls and roller massagers). Not only similar results were found when different SMR instruments were administrated (63, 100), but the time performing it also affected the flexibility-related outcomes regardless of the technique

(58). Still in the SMR techniques and characteristics, differences between different types of foam rollers were found, as well as self-administered and instrument-assisted myofascial techniques. The studies showed that vibrating and higher density foam rollers were more beneficial that non-vibrating or lower density foam rollers (11, 15, 26, 48, 80). Furthermore, instrument-assisted soft tissue mobilization may be superior to foam rollers in order to increase the knee and hip ROM (51). Moreover, the way it is performed may also affect the results, as active movement when rolling may be more beneficial in comparison to the usual rolling (i.e., no joint motion) (14). Finally, it seems that velocity performing roller motion (98), pressure applied (27) and guidance (c.f., video-guided vs live instructed vs self-guided) (12), does not influence the flexibility-related outcomes.

Muscular: Several muscular-related outcomes were evaluated in the studies, such as muscular contraction, jump performance, velocity, agility, functional activities and contractile properties. SMR groups in the studies reached mixed results. For example, Wiewelhove et al. (96) found that pre-rolling (+1.5%; g = 0.20) resulted in a small improvement in sprint performance (+0.7%; g = 0.28 (95% CI: -0.01 – 0.57)) whereas the effect on jump (-1.9%; g = 0.09 (95% CI: -0.14 – 0.31)) and strength performance (+1.8%; g = 0.12 (95% CI: -0.12 – 0.37)) was negligible; and post-rolling (+2.0%; g = 0.19) slightly attenuated exercise-induced decreases in sprint (+3.1%; g = 0.34 (95% CI: -0.09 – 0.78)) and strength performance (+3.9%; g = 0.21 (95% CI: -0.17 – 0.59)) whereas the effect on jump performance (-0.2%; g = 0.06 (95% CI: -0.28 – 0.41)) was trivial. However, pooled data shows that at least it did not impair the evaluated outcomes. Interestingly, the SMR groups reached more positive results in outcomes that involve flexibility in some way, such as agility (20, 78) and functional activities (9, 74). This may be the most important factor when the practitioner has to choose between interventions. As discussed in the last sub-group, the most important intervention to improve flexibility-related outcomes was static stretching, being SMR a comparable intervention with dynamic stretching and PNF. However, it has been well established that applying static stretching to a muscle (or muscular group) may lead to an acute loss of strength after the stretching has been completed (52). This effect has been referred as stretch-induced strength loss (52). This effect was also found in the included studies, where static stretching had more adverse muscular-performance results in comparison with either dynamic stretching or SMR (31, 38, 48, 82, 91). Therefore, in these outcomes SMR using instruments seems to be a more valid option in comparison with static stretching.

In other outcomes, the SMR groups performed as well as the control groups. Nevertheless, in some of the studies the outcomes were analyzed according only to the statistical data. However, in the "real" world, sometimes small and non-statically significant changes may be the difference between winning and losing. For example, in the Mikesky et al. (54) study a 0.02-second decrease in the 20-yard dash time on the SMR group was found. Although the difference was so small and not powerful enough to be statistically significant, this may deeply influence the final outcome, and be worthwhile doing such intervention (35). So, even if the studies reported a non-significant difference between groups, all data needs to be carefully analyzed, because it could have practical implications. This is further validated by the enhance of positive effects in muscular-related outcomes after adding SMR techniques in dynamic warm-up protocols (65, 73).

As described in the previous sub-group, other SMR instrument-related factors may influence the outcomes. Time was one of the most explored factors. Pooled results show that foam rolling volumes equal to or greater than 60-seconds are detrimental to the ability to continually produce force in the lower extremity (10, 57, 59, 61, 62, 75). It was also found that the greater the pressure applied against the roller, the lower the H-reflex achieved (101). This may explain some of the results obtained in the muscular-related outcomes after applying a SMR technique, as well as the effects found between different rolled sites (e.g., muscle vs fascia). Finally, it seems that vibrating rollers may be more beneficial than conventional ones, especially in improving proprioception (48, 80).

Recovery

Recovery-related outcomes were reported in almost all systematic reviews included (13, 33, 37, 79, 87, 96). Overall, there was compelling evidence that SMR instruments seems to be beneficial for recovery after exercise-induced muscle damage (EIMD), delayed onset muscle soreness (DOMS) and other physical performance decreases. The benefits may be encounter up to 72 h following a muscular damaging (37, 87). However, it should be noted that the recovery of physical performance means that SMR is effective to bring physical performance back to baseline, i.e, SMR may be beneficial for athletes to recover and return to their normal performance and (33).

The 90-120 seconds range seems the most beneficial to enhance recovery-related, whereas times under 45 seconds may be insufficient for adequate recovery (37). Most of the studies were performed between SMR and placebo/sham intervention/no intervention. From these studies only a small number did not show differences between the groups in recovery-related outcomes (20, 102). However, even these studies found positive benefits or errors that may explain the results. In the D’Amico and Gillis (20) study, although no differences were found in the perceived muscle soreness between groups, the SMR group performed better in the agility test than the control group after EIMD. So, the authors concluded that SMR may be useful for athletes requiring adequate agility and need to recover quickly from demanding bouts of exercise. In the other study performed by Zorko et al. (102), the fatigue protocol may not have been sufficient to promote large differences in the participants. So, this may explain the lack of differences found between groups. Moreover, the small number of participants (n = 10) and the evaluation only in the short-term, may also influence the statistical results. Nevertheless, the authors concluded that, even if SMR does not have a superior effect over passive rest on short-term recovery, no detrimental effects were noted in other outcomes, so rolling may be an option for short-term recovery (despite this may rely only in psychological effects – sense of relaxation and lower perceived ratings of fatigue).

For DOMS, several conservative interventions can be applied to reduce the symptoms. However, it seems that athletic massage and light exercise may be the most promising in reducing DOMS (16, 18, 23, 69, 93). Comparing with no intervention, SMR and massage were superior in reducing pressure-pain threshold, with no differences found between massage and SMR (1). Regarding light exercise, one of the most used activities is running. So, Kalén et al. (40) compared the effects of rest, SMR and running on DOMS, and found that post recovery lactate levels were significantly lower for foam rolling (4.4 ± 1.5 mmol/l; p = 0.005; d = 0.94) and running (4.9 ± 2.3 mmol/l; p = 0.027; d = 1.21) compared with resting (7.2 ± 2.5 mmol/l). Furthermore, there was no statistically significant difference between foam rolling and running (p = 1.000). So, it seems that foam rolling is an effective method, as running, for recovery after performing a 100-meter water rescue.

As found in the performance-related outcomes, higher pressure (1) with active joint motion (14) in medium density foams (15) vibration rollers (11, 80), may have enhance benefits compared to light pressure in non-vibrating soft or hard foams. Once again, guidance does not seem to influence the final outcomes (12). Neural and vascular physiological effects may be the principal factors associated with the benefits of SMR in recovery. For example, after foam rolling, a reduction of blood cortisol level (43) and pain of latent myofascial trigger points (99) was found. However, these may not be the only physiological responses that explain the effects found. So, other explanations will be deeply explored in the section below.

SMR physiological responses and adverse effects

A number of physiological responses have been proposed, that can be divided into three main categories: vascular, mechanical and neuronal.

Regarding the vascular alterations, it is hypothesized that SMR using instruments will increase blood flow. This increase of blood flow may be due to the co-contractions found during rolling (10). These contractions would generate heat from the metabolic reactions, increasing local temperature and blood flow (10). Also, it was found that the constant rolling reduces arterial stiffness, increases arterial tissue perfusion, and improves vascular endothelial function (36, 70, 81). With this alterations, it is expected that a prosperous environment to enhance cellular waste products removal, decrease edema, and enhance tissue repair/healing will be created (16, 74). Increased blood flow also hinders the margination of neutrophils and reduces prostaglandin production, subsequently decreasing inflammation (81, 89). Furthermore, it may increase oxygen delivery, which encourages mitochondrial resynthesis of ATP and the active transport of calcium back into the sarcoplasmic reticulum (3). Because it is essential to apply constant pressure to correctly perform SMR using instruments, other systematical biochemical effects may be encountered (74): [1] smaller increases in postexercise plasma creatine kinase; [2] activated mechanosensory sensors that signal transcription of COX7B and ND1, indicating that new mitochondria are being formed and presumably accelerating the healing of the muscle; and [3] less active heat-shock proteins and immune cytokines, reflecting less cellular stress and inflammation.

Beyond these effects (more recovery-related), it is also theorized that the increase of blood flow plus the co-contraction and friction may reduce muscle tension and alter the connective tissue properties, thereby enhancing ROM (10). By the way that SMR is performed, a change of the viscoelasticity and thixotropic properties of the fascia are expected, promoting a more gel-like state without any impairment to the neuromuscular properties (10, 71). There is some speculation that sustained static positions, traumas or inflammation may cause abnormal crosslinks and scar tissue, leading fascia to lose flexibility, becoming restricted/thick/colloidal (5, 32). So, in one hand, heat will help to soften and reduce the viscosity of the tissue, in another hand, friction will induce mechanical stress that break apart scar tissue and remobilize fascia back to its gel-like state (10, 50). In recent years, by the increase of developed studies in the area, more importance was given to the role of fascia during muscular contraction and ROM (90). For example, Grieve et al. (29) found that SMR in the plantar aspect of the foot significantly increases the sit-and-reach outcome in comparison to the control group. So, the hypothesized effects of SMR on fascia are those that may be of greater importance regarding short-term ROM improvements. However, in colloidal substances, the thixotropic effect only lasts as long as the pressure or heat is applied and, within minutes, the substance returns to its original gel state (83). Therefore, it is unlikely that SMR would have a sustained effect on flexibility by changing the thixotropic property of the fascia. Additionally, Hall and Smith (30) found that SMR over the gluts was more effective than SMR in the iliotibial band to increase the hip ROM. Moreover, Monteiro et al. (57) found that foam rolling in the hamstring changed the shoulder passive ROM. Therefore, other theories have to explain the benefits of SMR beyond the "traditional" one.

Another theory raised is that the co-contractions may result in an increase of ROM through neuronal mechanisms similar to contract-relax PNF stretching (10, 14). In the contract-relax method, the Ib afferent fibers (within the Golgi tendon organs) and the signals progress to the central nervous system nuclei that controls the tonus are activated, causing a great inhibitory influence on the descending pathway (responsible of the modulation of muscle's tonus) (30, 34). This may explain the similar results found between PNF and SMR. However, in this autogenic inhibition process, Golgi tendon organs may be insensitive to the tension produced on the tendon through stretching (96). If stretch-induced inhibition exists, it is more likely to occur with large-amplitude stretches and not from the small tensile forces exerted during SMR (96). So, inhibition subsides almost immediately after the cessation of the tension in the tendon (96). Therefore, it seems unlikely that this mechanism would contribute to the positive effects of SMR. Still in the neuronal factors, vigorous pressure placed on the soft tissue may overload the activation of percutaneous mechanoreceptors and proprioceptors, possibly diminishing the sensation of the stretch endpoint and increasing stretch tolerance (1, 10, 50, 95). By the gate-control theory, this stimulus result in an afferent signal, transported along the myelinated fibers (Aα and Aβ), that leads to an inhibition in the spinal cord posterior horn, namely the nociceptive input C fibers (53, 55). The other central nervous system pain-modulatory mechanism proposed is the diffuse noxious inhibitory control (1, 10). This inhibitory control is evoked by a nociceptive stimulus (such as, heat or high pressures) that ascends from the spinal cord to the brain and, in return, the brain inhibits pain transmission monoaminergically, which leads to reduced pain perception not only locally but also at distant sites (47, 76, 85). In fact, researchers (101) found that rolling leads to a reduction of spinal excitability, which provides evidence for these theories. Associated to these theories are the parasympathetic reflexes and the gray matter-opioid system, responsible for changes in biochemical substances such as serotonin, noradrenaline, cortisol, endorphin, oxytocin and endocannabinoids (1, 39, 61, 94). All these mechanisms previously described may explain the pain reduction found after SMR (1, 14, 96).

Finally, it is proposed that SMR mechanical stress removes trigger points from muscle tissue. For example, in the Wilke et al. (99) study, static SMR using a foam roller demonstrated to be an effective intervention in reducing pressure pain of latent trigger points. Nevertheless, there is controversy about the proof, identification and treatment of trigger points (1, 49, 67, 77). In fact, in a recent review developed by Quinter et al. (77), although not denying the existence of real clinical phenomena, the group deeply criticized and refuted the myofascial trigger points theories and concepts. Therefore, this theory needs further studies to be clarified.

Practical orientations

It seems that SMR using instruments is a beneficial intervention to increase ROM and recovery from DOMS/EIMD, without major muscular impairments (13, 33, 37). While performing SMR, some athletes refer pain or discomfort when doing the rolling motion (10). However, although it is important to apply pressure, it was been shown that the increase of pain does not equal more performance nor recovery benefits (27). So, it is advised to perform the SMR only with the bodyweight or with forces up to 50% of maximum discomfort. When performing the rolling motion, it is also advised to do active joint motion (14). Still in the way of SMR performing, there is some evidence that shows that to have beneficial effects it does not required doing rolling motions in the same location over 1 minute. Although it was found that, in some outcomes, the more the rolling time the more benefits were found (10, 57, 59, 60, 75, 92), rolling more than 60 seconds may have detriments in the muscular-related performance outcomes (10, 57, 59, 61, 62, 75). Also, apparently, the speed performing rolling it does not influence the SMR effects (98). However, the pooled data gathered in the Behm et al. (7) study, showed greater effect sizes in 1-3 sets (d = 0.83 – 1.1) with a speed of 2-4 seconds (d = 1 – 1.85) ranges. So, speed may still be a potential effect modifier that need further analysis. Nevertheless, it was found that, in average, the SMR effects are of short-term and may not pass the 10-minute range (42). Therefore, even if the sport required more muscular-related outcomes, SMR can be safe to perform 10 minutes before the warm-up to a training/competition, not only to enhance flexibility and/or agility but also to diminish pain/discomfort related to DOMS/EIMD, eventually boosting sports performance (13, 33). As SMR effects need a small amount of time to emerge the effects, its use might be even more important in sports with tournament scheme competition, where are several matches in a day with little time to recover between them.

Regarding the SMR instruments characteristics, there is some evidence that, in case of doubt, foam rollers should be chosen over roller massagers (96) and those must be of medium density foam (instead of low and high density) (15). Preferentially, the foam rollers should be composed of a PVC pipe (for reducing weigh, and to apply higher and constant pressure) (19). Furthermore, vibrating foam rollers should be chosen over the non-vibrating ones (11, 26, 48, 80). This may rely with the mechanical and neuronal physiological effects enhance, explained in the previous section.

Based on the included studies, it was found that SMR using instruments is beneficial to enhance short-term flexibility-related and recovery-related outcomes. Inconstant data was reported in muscular-related outcomes. Nevertheless, beyond pain during SMR, no major adverse effects were found in the evaluated outcomes. Furthermore, different effects between time, pressure and other instruments characteristics were found. So, SMR using instruments can be a safe intervention used in sports to enhance performance (especially in those where flexibility is a fundamental physical parameter) and recovery from previous trainings/competitions or between matches.

One limitation of this umbrella review include the small number of systematic reviews found. Although the introduction of instruments for SMR are relatively new into the daily practice, only 15 systematic reviews were found in this study. Additionally, from those systematic reviews only 7 had at least moderate methodological quality (B) to be included (none of high-quality). Furthermore, from the 7 systematic reviews, structural errors in reporting the included studies were found, including: omission of non-statistically significant differences (focusing only in the positive results of the SMR instruments); misconception of the outcome reported; and overall missing data that influences the appraisal and critical analysis of the studies. Another limitation, was the duplication of studies included in the systematic reviews. Of the 168 explored studies, the exploration of the same studies twice or more between systematic reviews was found. Finally, many of the studies have the same group members either as main or as co-authors. Although, it is important to include experts as team members to help design, develop and analyze studies, including the same authors throughout the studies may have increased the risk of bias.

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