A SYSTEMATIC REVIEW AND META-ANALYSIS OF THE EFFECTS OF FOAM ROLLING ON **RANGE OF MOTION AND** MARKERS OF ATHLETIC PERFORMANCE

ABSTRACT

Objective: Conduct a systematic review with meta-analysis assessing the effects of foam rolling on range of motion, laboratory- and field-based athletic measures, and on recovery.

Data sources: MEDLINE, PubMed, EMBASE, SPORTDiscus and Science Direct were searched (2005-June 2018).

Study selection: Experimental and observational studies were included if they examined the effects of foam rolling on measures of athletic performance in field or laboratory settings. Studies were excluded if they involved myofascial modalities other than foam rolling.

Data extraction: Two investigators independently assessed methodologic quality using the Physiotherapy Evidence Database (PEDro) Scale. Study characteristics including participant age, sex and physical activity status, foam rolling protocol and pre- and post-intervention mean outcome measures were extracted.

Data synthesis: A total of 32 studies (mean PEDro = 5.56) were included in the qualitative analysis, which was themed by range of motion, laboratory-based measures, field-based measures and recovery. Thirteen range of motion studies providing 18 datasets were included in the meta-analysis. A large effect (d=0.76, 95% CI 0.55-0.98) was observed, with foam rolling increasing range of motion in all studies in the analysis.

Conclusions: Foam rolling increases range of motion, appears to be useful for recovery from exercise induced muscle damage, and there appear to be no detrimental effect of foam rolling on other athletic performance measures. However, except range of motion, it cannot be concluded that foam rolling is directly beneficial to athletic performance. Foam rolling does not appear to cause harm and seems to elicit equivalent effects in males and females

INTRODUCTION

Fascia is described as a key component of connective tissue (Threlkeld 1992), where myofascia wraps and encases muscles, forming connective chains running from the cranium to the toes (Meyers 2013). It has been proposed that when negatively altered through modified muscle function, i.e. from overstress, injury, imbalance or fatigue (MacDonald et al 2013a), fascia can stiffen as a result of the development of fascial crosslinks and can consequently generate uneconomical movement patterns (Bushell et al 2015; Kaltenborn 2006). The change in fascia quality is suggested to negatively influence sporting performance (MacDonald et al 2013b).

Myofascial release is a therapeutic intervention for releasing soft tissue from areas of abnormally tight fascia (Miller & Rockey 2006; Prentice 2003). Myofascial release treatment involves targeted, directional low loading mechanical forces aimed at restoring optimal tissue length and improving function (Ajimsha et al 2015). High or sustained pressure applied via myofascial release is suggested to cause golgi tendon organs to detect sensations of altered tension in the musculature, eliciting relaxation of muscle fibres (Miller & Rockey 2006). A popular approach to self-myofascial release (SMFR) has emerged in the form of foam rolling, a technique whereby individuals use their own body mass to exert compressive rolling forces along targeted musculature, following the orientation of the specific muscle being mobilized (Pearcey et al 2015).

The use of foam rollers in athletic and recreationally active populations has seen notable increases in recent years due to myofascial release being associated with performance enhancements (Barnes 1997; MacDonald et al 2013b; Renan-Ordine et al 2011). Advocates of foam rolling contend that it can assist in correcting muscular imbalances, improve neuromuscular efficiency, improve range of motion and improve markers of strength and power

(Curran et al 2008; Peacock et al 2014; Peacock et al 2015; Škarabot et al 2015; Swan & Graner, 2002). While conflicting evidence has been reported into the efficacy of foam rolling in these areas (Healy et al 2015; Peacock et al 2014; Roylance et al 2013), importantly, it is suggested that the benefits reported have occurred without negative effects on physical performance (Halperin et al 2014; Sullivan et al 2013).

Since 2013, there has been a proliferation of literature published that evaluates the effects of foam rolling on a variety of markers of athletic performance and has included evaluation pre- and post-exercise (Cavanaugh et al 2017; D'Amico & Paolone, 2017; Janot et al 2013; MacDonald et al 2013a; Pearcey et al 2015). As an indication of the contemporary interest in this area, **three reviews have been published since 2015 (Beardsley & Škarabot, 2015; Cheatham et al 2015 and Wiewelhove et al 2019),** however these reviews have not focused solely on the application of foam rollers, have included other modalities (for example roller massage, stick, blades, tennis ball) **or** have included broad outcome measures beyond markers of athletic performance, for example on arterial function**. To the best of our knowledge, no quantitative synthesis via meta-analysis specifically focusing on the effects of foam rolling has been conducted to date and therefore the pooled effects are unknown**. **Given the wide uptake of foam rolling among recreational and professional athletes, meta-analysis of this topic would strengthen the ability to specifically draw conclusions on the effectiveness of foam rolling as an intervention which will be beneficial to both users and healthcare practitioners**. Therefore, the purpose of this study was to;

1) critically appraise the current evidence specific to foam rolling on markers of athletic performance and recovery via qualitative synthesis
2) establish the effect of this treatment intervention via meta-analysis
3) establish if harmful effects of the application of foam rolling have been published

METHODS

A protocol for this study was registered with PROSPERO (Hammond et al 2015).

Search strategy

MEDLINE, PubMed, EMBASE, SPORTDiscus, and Science Direct databases were searched for English language, peer reviewed sources. The search strategy for MEDLINE is presented in Table 1. In addition, Current Controlled Trials and the WHO International Clinical Trials Registry Platform for ongoing and recently completed trials were searched, as well as the table of contents of the following journals: British Journal of Sports Medicine, Medicine and Science in Sports and Exercise, Journal of Athletic Training, The Journal of Strength and Conditioning Research and Strength & Conditioning Journal. All searches were conducted from 2005 to 14th June 2018. Following the search, reference lists were reviewed, and subsequently electronic forward citation searches were conducted in Google Scholar for all relevant articles located. Experts and colleagues working in the subject area were also asked to notify the authors on the existence of new or ongoing studies, which were also considered for inclusion.

Insert Table 1 here

Inclusion and exclusion criteria

Randomized controlled trials, clinical trials, cross-over studies and quasi-experimental studies evaluating the use of self-myofascial release via a foam roller in laboratory or field settings for athletic performance in male or female adolescents (>15 years) and adults were included in this review. Studies included in which at least one group in the trial comprised participants treated with foam rolling before or after exercise. Foam rolling was defined as self-myofascial release involving a repetitive rolling action over a muscle group using any type of foam roll e.g. dense or rigid. Studies including single or multiple bouts of foam rolling within a single session or over more than one day were included. The authors aimed to include trials that compared the use of foam rolling versus a passive or control intervention (rest, no treatment or placebo treatment) or active interventions including, but not limited to, warm up, cool-down, stretching, massage baseline measures or exercise. It also aimed to include trials that compared different durations or dosages of foam rolling.

Studies involving on injured participants and sedentary individuals and studies focusing on other myofascial modalities (static trigger point massage with an implement, therapist applied roller massage or myofascial release, and therapist or self-applied instrument assisted myofascial techniques) were excluded. Trials that did not report any of the primary outcomes were also not included in the review.

Primary outcomes

1) Flexibility, range of motion
2) Muscle contractile properties (e.g. maximal voluntary isometric contraction (MVIC), muscle power, muscle strength/activation, peak torque)
3) Maximal oxygen uptake
4) Markers of fatigue (e.g. lactate)
5) Speed, acceleration, agility, reaction time
6) Exercise-induced muscle damage, delayed onset muscle soreness (DOMS)

Secondary outcomes

1) Adverse effects of foam rolling
2) Differences of effects between males and females

Study selection

Two review authors (BS, RM) independently selected trials for inclusion. After the removal of duplicates, the titles and abstracts of publications obtained by the search strategy were screened, and any study that was obviously outside the scope of the review removed. The full text of any papers that potentially met the review inclusion criteria were obtained. The same two review authors then independently selected trials for inclusion in the review according to the inclusion and exclusion criteria, using a standardized form to record their choices. In the event of disagreement between the review authors, this was resolved by consensus or by third party adjudication (LH).

Quality assessment

To assess for risk of bias in the included studies, two review authors (BS, RM) independently assessed risk of bias of studies meeting the inclusion criteria using the PEDro scale (http://www.pedro.org.au/english/downloads/pedro-scale/). To minimize bias in the interpretation of this scale, prior to assessing the included studies, the review authors assessed three unrelated studies that were not included in the current review; disparities in judgements were reviewed and discussed before any of the included studies were evaluated. Each of the included studies was graded for risk of bias by being assigned a score from 0-10 (criterion 1 was excluded from the score according to PEDro guidelines), and were considered to be moderate to high quality if achieving a score of ≥ 6 (http://www.pedro.org.au/english/downloads/pedro-statistics/). Any disagreements between review authors regarding the risk of bias assessment were resolved by consensus or by adjudication of the third author (LH).

Data extraction

A customized form was created for data extraction (to obtain study details on methodology, eligibility criteria, interventions including detailed characteristics of the exercise protocols and the foam rolling protocol employed, comparisons, outcome measures and participant characteristics including age, sex and sporting level). Subsequently, one review author (LH) independently extracted relevant data for the remaining included papers. Data was extracted for immediately post-foam rolling, as well as further follow up times where reported. For studies involving DOMS, the typical follow-up times of up to 1, 24, 48, 72, 96 and more than 96 hours post intervention were used. Primary authors were contacted to obtain or clarify any omitted data.

Statistical Analysis

All of the data extracted were examined by the review authors in order to determine their suitability for meta-analysis. For range of motion, 18 data sets from 13 studies that were deemed comparable were identified and these data were included in the meta-analysis. For each of these, Cohens d and Confidence Intervals (95% CI) were calculated to establish the effect size from pre- to immediately post-foam rolling. For all studies with the exception of one (Couture et al 2015), an increase in score indicated a positive effect of the treatment. For Couture et al (2015), in which an increase in score corresponded to a negative effect of treatment, the effect size was multiplied by –1 to ensure all scales pointed in the same direction (Leard et al 2007). Assessment of heterogeneity between comparable trials was evaluated with I^2 statistics. Values of I^2 were interpreted as follows: 0% to 40% might not be important; 30% to 60% may represent moderate heterogeneity; 50% to 90% may represent substantial heterogeneity; and 75% to 100% may represent considerable heterogeneity (Leard et al 2007). Results of the comparable trials were pooled using a random-effects model. The choice of the model was guided by the moderate heterogeneity identified (Neyeloff et al 2012). For other thematic areas e.g. DOMS, there were insufficient trials or studies were too heterogenous in order to perform meta-analysis.

RESULTS

Included Studies

Two hundred and thirty-four potential articles were identified from the search (Figure 1). Of these, 197 were excluded based on the title or abstract. Thirty-two articles met the inclusion criteria. All included studies were published over a five-year period (2013-2018), indicating the contemporary interest in this area. The mean PEDro score of these papers was 5.56 (Table 2). The papers were organised into the following themes for analysis: range of motion (Behara & Jacobson 2015; Bushell et al 2015; Cheatham et al 2017; Couture et al 2015; Garcia-Gutiérrez et al 2017; Griefahn et al 2017; Junker & Stöggl; Kelly & Beardsley 2016; MacDonald et al 2013b; Macgregor et al 2018; Markovic, 2015; Mohr et al 2014; Monterio et al 2018; Morales-Artacho et al 2016; Morton et al 2015; Peacock et al 2015; Roylance et al 2013; Škarabot et al (2015); Su et al 2016; Vygotsky et al 2015), laboratory based measures (Behara & Jacobson 2015; Cavanaugh et al 2017; D'Amico and Paolone 2017; Garcia-Gutiérrez et al 2017; Healy et al 2015; Jones et al 2015; Janot et al 2013; MacDonald et al 2013b; Macgregor et al 2018; Monterio et al 2017; Morales-Artacho et al 2016; Morton et al 2015; Su et al 2016), field based measures (Behara and Jacobson, 2015; Healy et al 2015; Jones et al 2015; Peacock et al 2014; Peacock et al 2015) collectively presented in Table 3 and recovery (Fleckenstein et al 2017; Kalén et al 2017; MacDonald et al 2013a; Pearcey et al 2015; Romero-Moraleda et al 2017) (see Table 4). Of the 20 studies identified that focussed on foam rolling and range of motion, eight were subsequently excluded from the meta-analysis due to an inability to calculate an effect size for the study as raw data were unavailable (MacDonald et al 2013b; Peacock et al 2014; Peacock et al 2015; Roylance et al 2013; Kay & Blazevich, 2012; Macgregor et al 2018; McHugh & Cosgrave 2010; Morales-Artacho et al 2016), due to methodological heterogeneity (Vygotsky et al 2015) and one where the intervention was applied for recovery purposes (MacDonald et al 2013a).

Insert Figure 1 here

Insert Table 2 here

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Insert Table 4 here

Range of motion studies

The largest number of studies located (n=20, pooled mean age 22.72 ±3.32 years) investigated effects of foam rolling on range of motion. The mean PEDRO score was 5.60. Thirteen studies investigated range of motion measured in degrees (Behara & Jacobson 2015; Bushell et al. 2015; Cheatham & Baker 2017; Couture et al 2015; MacDonald et al 2013b; Macgregor et al 2018; Mohr et al 2014; Monterio et al 2018; Morales-Artacho et al 2016; Morton et al 2015; Su et al 2016; Vygotsky et al 2015) and nine studies investigated muscle length measured in centimetres (Garcia-Gutiérrez et al 2017; Junker & Stöggl, 2015; Kelly & Beardsley, 2016; Peacock et al 2014; Peacock et al 2015; Roylance et al 2013; Su et al 2016; Vygotsky et al 2015), with all studies involving foam rolling to the lower limb or trunk. Only two of these studies included investigations of effects of range of motion taking place over more than one day (3 days [Macgregor et al 2018] and 3 weeks [Bushell et al 2015]).

The meta-analysis included eighteen effect sizes from thirteen studies reflecting a total of 330 participants (see Figure 2). All effect sizes were positive, indicating an improvement in range of motion following foam rolling, and the weighted mean effect size was *d*=0.76, 95% CI (0.55-0.98), large effect.

Insert Figure 2 here

Laboratory based measures

Thirteen studies investigating a wide range of laboratory-based outcomes, including torque, velocity, power, impulse, force, tendon stiffness, maximal voluntary contraction, electromechanical delay, half relaxation time, EMG and tetanus, were identified. Twelve of these studies involved recreational athletes and one study was performed with elite collegiate athletes (Behara & Jacobson 2015) (pooled mean age 22.70 ±3.30 years). Seven studies involved male participants, one involved female participant and the remaining five investigated males and females together. The mean PEDRO score was 5.85. The majority of papers focused on acute responses, with two studies investigating foam rolling over more than one day (3 days [Macgregor et al 2018] and 4 days [Monterio et al 2017]).

Field based measures

In the five studies included for analysis of field-based measures, outcomes investigated included power, speed, velocity, strength, force and agility. All five investigations were conducted with physically or recreationally active individuals to lower limb muscles, (pooled mean age of 22.02 ± 1.93 years) with only one investigation including female subjects (Healy et al 2015). The mean PEDro score of these studies was 4.20 which is the lowest methodological quality identified for this review. No field-based studies were identified that investigated the effect of foam rolling on field-based measures over more than one day.

Measures of recovery

Five studies were located that investigated the effect of foam rolling on recovery from exercise (See Table 4). All were conducted in young participants (pooled mean age 23.36 ±2.91 years), and the mean PEDro score of these papers was 5.6. Two studies used the same muscle damage protocols to induce DOMS, and measured performance parameters at pre-test, post 0 hours, post 24 hours, post 48 hours, post 72 hours (MacDonald et al 2013a; Pearcey et al 2015), whereas Romero-Moraleda et al (2017) took measurements at baseline, immediately post- and 48 hours post-damaging exercise, with the foam rolling delivered at 48 hours post-exercise. Two further studies examined the effect of foam rolling on recovery, but not from eccentric, damaging exercise; Fleckenstein et al (2017) considered the effects on neuromuscular fatigue 5 minutes after a fatiguing protocol, and Kalén et al. (Kalén et al 2017) looked at lactate clearance following a simulated water rescue in lifeguards.

Adverse Effects of Foam Rolling

No studies included within this review identified any adverse or harmful effects from the application of foam rolling.

DISCUSSION

This systematic review and meta-analysis present a novel set of findings on the effects of foam rolling on a range of important athletic measures. This work represents a new synthesis of contemporary evidence with this popular tool.

Effect of foam rolling on range of motion

This review shows that foam rolling has a large, positive effect upon range of motion immediately following application (d=0.76, 95% CI (0.55-0.98)), and that the positive effects of foam rolling on range of motion are elicited irrespective of the measurement method, the foam rolling dosage application or the sex of the participants. Foam rolling has been shown to consistently bring about an increase in both joint range of motion and muscular length. For an athletic population, the importance of a change in range of motion is dependent upon multiple factors such as the joint involved, individual baseline measurement and/or the specific demands of a given sporting activity. The minimum clinically important difference for hip flexion for example, has not yet been established however the values found in this analysis are in agreement with published evidence within this field (Hammer et al 2017). The increase in range of motion observed may be attributed to a number of factors including tissue extensibility, temperature, perfusion, fatiguing factors, realignment of tissue fibres (Madding et al 1987; McHugh & Cosgrave 2010; Gajdosik 2001; Wepple & Magnusson 2010). However, while the acute effects are evident, the chronic effects are not, and it cannot be concluded that foam rolling has a positive effect on range of motion or flexibility over time. It should also be noted that a wide range of methods were used to assess range of motion, and while these are well established (e.g. goniometry, inclinometry, isokinetic dynamometry, sit and reach test amongst other) and have generally shown good to excellent levels of reliability (Charlton et al 2015;

Drouin et al 2004; Kolber & Hanney 2012; Konor et al 2012), measurement error could contribute to these positive findings.

Effect of foam rolling on laboratory-based measures

Findings are equivocal with regards the effects of foam rolling on laboratory-based measures. Seven investigations found no significant improvements (Behara & Jacobson 2015; D'Amico & Paolone 2017; Garciz-Gutiérrez et al 2017; Healy et al 2015; Jones et al 2015; Morales-Artacho et al 2016; MacDonald et al 2013b), and seven studies showing significant positive effects (peak power output and percentage power drop [Janot et al 2013], passive peak torque [Su et al 2016], rate of torque development, maximal voluntary contraction and tendon stiffness [Morton et al 2015], protecting the decline in MVIC [Macgregor et al. 2018], reduced EMG [Cavanaugh et al 2017], improved FMS score [Monterio et al. 2017], reduced muscle stiffness and increased knee extension peak torque [Morales-Artacho et al 2016]). However, inconsistencies are apparent in the application of the foam rolling between studies, with protocols ranging from a single 30 second bout per muscle through to ten sets of 60 seconds, making direct comparison of studies 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 (Behara & Jacobson 2015; D'Amico & Paolone, 2017; Healy et al 2015; Jones et al 2015). This suggests that a dose-response relationship may be present. There were also no differences in responses found between male and female participants. To explain the increases in performance measures, it has been proposed that myofascial release may result in increases in alpha-motor neuron activity and output, while subjects who undertook foam rolling are also able to maintain muscle activity due to less neural inhibition as a result of healthier connective tissue permitting better communication from afferent receptors in the connective tissue (Janot et al 2013; MacDonald et al 2013a). **No studies were identified for investigation of the effect on maximal oxygen uptake.**

<u>Effect of foam rolling on field-based measures</u>

Collectively the evidence suggests that there is no detrimental effect of up to 120 seconds of pre-exercise foam rolling on subsequent field-based measures. Four studies (Behara & Jacobson 2015; Healy et al 2015; Jones et al 2015; Peacock et al 2015) indicated that lower limb foam rolling had no effect on power, speed and agility, and Peacock et al (2014) reported positive responses in these aspects of athletic measures following foam rolling. These findings show similarities with the literature on static stretching, for example, Kay & Blazevich (2012) proposed that short durations of stretching (<60 s) can be performed pre-exercise without compromising maximal muscle measures. Further to this, the results from foam rolling studies reflect positively against reports that suggest static stretching to single muscles over 100-seconds (2 sets x 50 s) may be detrimental to power-based activities e.g. counter movement jump (Cornwell et al 2001). However, no investigation included in this analysis has conducted foam rolling dosage greater than 120-seconds. The low to moderate quality rating of these studies indicate that the findings of these studies should be interpreted with caution. It has been proposed that the variability in effectiveness of foam rolling on field-based performance measures may lie in the complexity of the test itself (Pearcey et al 2015); minimal changes were reported for multidirectional tests (e.g. T-test), which are associated with greater degrees of motor control, co-ordination and multiple muscle interactions, in comparison to the more notable changes on unidirectional tests e.g. sprint test. As noted in relation to laboratory-based measures, there is inconsistency on the dosage of foam rolling applied making direct comparisons between studies difficult.

Effect of foam rolling on recovery

All studies identified appeared to show positive effects on foam rolling in the context of post-exercise recovery; for exercise-induced muscle damage/DOMS, studies support the use of a daily bout of foam rolling to lower limb muscles up to 72 hours following damaging exercise, compared to no intervention at all. Foam rolling attenuated the effects of muscle damage on muscle soreness/pain threshold, range of motion and performance-based measures of power and speed. However, there were no beneficial effects found for swelling, and evoked contractile properties. In their paper, MacDonald et al (2013a) considered the possible mechanisms for the observed beneficial effects of foam rolling and suggest that foam rolling appears **to** have a beneficial effect on the connective tissues, most probably at the myotendinous junction, rather than being beneficial to muscle recovery; this is suggested on the basis that there was reduced muscle soreness while also having greater decrements to evoked contractile properties. They propose that the decrease in pain may have resulted in less neural inhibition. Collectively, this appears to make foam rolling helpful for dynamic movements. Foam rolling was also found to be beneficial compared to passive recovery for lactate clearance (Kalén et al 2017) and demonstrated a non-significant trend for attenuating the effects of neuromuscular fatigue, measured by perceived exhaustion, muscle force and reactive strength index (Romero-Moraleda et al 2017). In the wider literature, studies of DOMS, common methods to attenuate the symptoms include nutritional and pharmacological strategies, electrical, manual and cryotherapies, and exercise (Howatson & Van Someren 2008). No study has compared foam rolling to these commonly used approaches to reduce the impact of DOMS, therefore it is not possible to identify whether foam rolling is any more effective than alternative, commonly adopted modalities. More recently published studies considering foam rolling and post-exercise recovery (Kalén et al 2017; Roylance et al 2013) have included comparators other than control (running and neurological mobilization respectively), which performed as effectively as foam rolling in attenuating the effects of the exercise protocols.

Limitations of the literature identified and generalizability of the results

The methodological quality of the studies performed in this area remain varied but has improved over time, with 18 of the 32 studies included in this review being considered as moderate to high quality, scoring 6 or greater on PEDro quality assessment (Behara & Jacobson 2015; Cavanaugh et al 2017; Cheatham et al 2017; D'Amico & Paolone 2017; Fleckenstein et al 2017; Garcia-Gutiérrez et al 2017; Griefahn et al 2017; Janot et al 2013; Kalén et al 2018; Kelly & Beardsley 2016; MacDonald et al 2013b; Macgregor et al 2018; Monteiro et al 2017; Monteiro et al 2018; Morales-Artacho, 2017; Romero-Moraleda et al 2017; Roylance et al 2013; Su et al 2016). Encouragingly, the more recently published literature appears to be of higher methodological quality, however, the findings reported in this review should be interpreted in light of the risk of bias associated with the studies included. More studies are needed with stronger methodological rigour in this area of inquiry.

More specific methodological concerns with the studies in this review include that some studies involved a large physical contact area and duration of foam rolling and large battery of performance measures, which has the potential to create inter-participant differences in both the fatiguing effects of a long bout of foam rolling, and differences in elapsed time from intervention to test. It is unclear whether randomization of order of both application of foam rolling, and measurement of outcome tests was undertaken in order to reduce the chance of order effects influencing the findings. Furthermore, foam rolling is, by its very nature, a self-limiting activity and it is not possible to normalize or standardize the degree of pressure exerted by the foam roller on the muscles when self-administered, as opposed to being administered mechanically (Bradbury-Squires et al 2015; Swan & Graner 2002). Collectively, these factors have the potential to impact on participant performance measures and therefore, study outcomes.

The studies identified through this systematic review have focussed on lower limb muscles and study populations comprise mainly of college-aged males. It is unknown whether the same effects of foam rolling found within this review are present in older or paediatric populations, or following foam rolling to the upper limb muscles. The question of whether foam rolling has benefits to endurance-based athletes also remains unanswered. The majority of studies have identified the acute effects of foam rolling, but whether a dose-response relationship exists is unclear. The studies that have explored the effects of foam rolling have looked primarily at the presence of effects but have not considered in detail why these effects have been brought about.

Limitations of this review

This is the one of the first studies to attempt a meta-analysis of data from foam rolling literature, however conducting the meta-analysis was challenging. It was only possible to calculate effect sizes from pre- to post-intervention, which does not account for control or comparator, which would be usual for meta-analysis. Additionally, some papers qualified to be included in the meta-analysis, but the data could not be accessed, and therefore they were excluded from the quantitative synthesis.

This review, while narrower than previous reviews conducted on foam rolling, is still broad in its scope and attempts to compare a wide range of parameters that have been investigated in a range of ways. This variation within the published literature was also present within the different domains of this analysis, as evidenced within the range of motion meta-analysis which demonstrated moderate heterogeneity. Many studies judged as having low methodological quality were included, which has the potential to introduce bias into the conclusions reported here.

Clinical Relevance

- In practical terms, these studies have demonstrated that it is neither harmful nor detrimental to performance for male or female athletes to perform foam rolling before or after activity.
- For athletes seeking an acute increase in muscle flexibility or joint range of motion, foam rolling is a useful tool to include as part of a warm up or pre-exercise activity.
- Coupled with the positive effects on muscle and tendon stiffness, this may be of particular use or importance for athletes involved in ballistic sports for which the stretch-shortening cycle is important (Morales-Artacho et al 2016).
- Foam rolling is beneficial for reducing some of the common symptoms associated with exercise induced muscle damage.
- Given its effectiveness, ease of application and relative comfort (compared to cold water immersion for example) and relatively low cost, it may be preferential to athletes over other recovery modalities that are available.

CONCLUSION

There is a clear beneficial acute effect of foam rolling on range of motion, however longer-term effects remain unknown. There appears to be no detrimental effects of foam rolling on other athletic performance measures, but it cannot be concluded that foam rolling is directly beneficial to athletic performance markers including **MVIC, muscle power, muscle strength/activation, peak torque, maximal oxygen uptake, speed, acceleration, agility or reaction time**. Foam rolling appears useful for recovery from activity, but it is not possible to state whether it is any more or less effective than other commonly used modalities. **Foam rolling does not appear to be harmful to an athlete through its application and while there are fewer studies that have included female participants, foam rolling seems to elicit equivalent effects in males and females**. It is noteworthy that there has been a proliferation of research in this area since 2013, and this review reflects the infancy of the major research in this field. In order to develop the evidence base in this field, future research should be directed towards the following areas;

1) developing a better understanding of whether there is an optimal dosage or dose-response relationship
2) investigation to determine the effects of long-term use of foam rolling to determine if any chronic effects exist
3) comparing the effects of foam rolling on DOMS with other commonly accepted approaches to recovery to damaging exercise, in order to better inform that body of evidence
4) conducting work into a more diverse population beyond young, active males, and considering its application for endurance-based athletes
5) developing a better understanding of the mechanisms by which foam rolling has its effect

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TABLES

CAPTIONS TO ILLUSTRATIONS

Figure 1 - PRISMA search strategy flow chart

Figure 2 - Forest plot to show the meta-analysis of foam rolling on range of motion