Acta Scientific Orthopaedics

Volume 2 Issue 2 February 2019

Research Article

Effect of Stretching including Proprioceptive Neuromuscular Facilitation and Muscle Energy Techniques on Injury Risks: A Systematic Review

Johnson Pok-Him Tam*

University of Bristol Faculty of Health Sciences, Senate House, Tyndall Ave, Bristol, England

***Corresponding Author:** Johnson Pok-Him Tam, University of Bristol Faculty of Health Sciences, Senate House, Tyndall Ave, Bristol, England

Received: November 02, 2018; **Published:** January 19, 2019

Abstract

Background: There is an increase in physical activity amongst the general population with the popularisation of health and fitness. Stretching is commonly practiced before sports participation. The effect of stretching on the risk of injury remains unclear. Studies of various level of methodological quality has shown conflicting results.

Aim: To assess the effectiveness of stretching in preventing injuries. To review the use of PNF and MET.

Methods: Ovid MEDLINE 1946-Present, EMBASE 1974-2017, Cochrane Library, Web of Science were used to search for literatures. The literatures were retrieved by the author and assessed according to a strict eligibility criterion. PEDro scale was used to assess the quality of the studies.

Results: 5 trials carried out between 1998-2010 were selected. They all assessed injury risks, but used different sample groups and stretching protocols, in addition to different statistical analysis. The difference in methodology design made some studies more valid than other studies.

Conclusion: Stretching was shown to reduce overuse injuries to some extent in militants and elite athletes, but there is not enough reliable and valid evidence to recommend the continuation or discontinuation of pre-activity stretching for injury prevention in the general population.

Keywords: Sport; Injuries; Stretch; Static Stretch; Dynamic Stretch; Proprioceptive Neuromuscular Facilitation

Introduction

According to the Health Survey for England 2012 [1], 67% of male and 55% of female aged over 16 met the national recommendations for physical activity (activities which equivalate to at least 150 minutes of moderate aerobic activity over a week), in comparison with 32% and 21% respectively in 1997. Average sedentary time also decreased in both males and females between 2008 to 2012 from 5 to 4.9 hours and 5 to 4.7 hours respectivly. This shows a promising rise in physical activity levels in the general population.

With an increase in physical activity, the number of people at risk for injuries has consequentially increased, therefore, injury prevention is vital. There are some standard practises carried out by athletes to reduce injury risks such as warm up along with stretching. Stretching is often recommended because of the common belief that it prevents injury [2-6]. However, the ability of stretching pre- and post- activity to prevent injuries has been questioned and it may even have an adverse effect on performance [7-9]. A decrease in strength post-stretching, regardless of methods of stretching and type of contraction has been reported.

There is limited conclusive evidence on the relationship between flexibility and incidence of injury and whether stretching prevents injury. Injury is often assumed to be related to low level of flexibility but being too flexible may increase injury risk [10], which is contrary to the common public perception. Reduced flexibility, however, doesn't correlate with the risk of muscle injuries sustained within a normal range of motion [11].

This review aims to outline different types of stretching, the various parameters such as range of motion, injury risk and performance that it affects. An emphasis is placed on pre-activity Proprioceptive Neuromuscular Facilitation (PNF) and Muscle Energy Techniques (MET) and their impact on injury risk. Data on the risk of injury associated with these types of stretching will be collected and reviewed to further understand the relationship between stretching and injury risk. As far as the author is concerned, there are limited reviews on the use of PNF and MET specifically on injury prevention.

Brief overview of different types of stretching

Most common types of stretching used by recreational and professional athletes include static, dynamic, ballistic stretching. More modern but perhaps less well-known alternatives are PNF and MET which are both popularising. Static stretching involves gradual lengthening of a muscle and holding an elongated position for a set time (between 30s to 120s) and is effective for increasing joint range of motion [12] and thought to improve performance. The sensitivity of tension receptors in stretched muscles are reduced which relaxes the muscle and relieve stress.

Dynamic stretching propels muscles near to their maximum range of motion without holding the muscle in a stretched position. It is differentiated to ballistic stretching as it doesn't involve a bouncing and uncontrolled movement in order to stretch a muscle beyond its range of motion. Dynamic stretching is now preferred over static stretching prior to physical activity because it maintains body temperature, enhances kinetic memory as athletes are doing movements that will be repeated in their physical activity and increases dynamic flexibility.

PNF stretching was first described by Herman Kabat [13] who used a combination of movements to relax stretched muscle and strengthen weak muscle by increasing inhibitory signalling in over-excited muscle, paired with increased excitation mechanism in the weakened muscle. It increases both passive and active range of motion, along with muscular strength and peak torque [14], in comparison to other stretching techniques. Contraction-relaxation and contraction-relaxation-antagonist contraction are the two main techniques for practising PNF. CR requires the lengthening and contraction of target muscle, followed by relaxation and passive stretching. CRAC differs from CR as it requires the antagonist muscle of the target muscle to contract instead of passive stretching. PNF works through four different physiological mechanism to increase ROM: autogenic inhibition, reciprocal inhibition, stress relaxation and gate control theory [15].

The two major mechanisms in PNF are autogenic inhibition and reciprocal inhibition. Autogenic inhibition refers to inhibitory signals sent from Golgi tendon organs (GTO) leading to decreased excitability in a over-stretched muscle to prevent muscle tear. Inhibitory neurons in the spinal cord is activated by Type Ib afferent fibres in GTO and as a result, motor (efferent) drive to the muscle is decreased. Muscle relaxation allows elongation of the muscle to increase ROM. Reciprocal inhibition is the relaxation of an antagonist muscle when the agonist muscle is contracted to prevent co-contraction of the pair which could cause muscle tear. This occurs because afferent muscle fibres of the contracted muscle (agonist) splits into two different motor neurons in the spinal cord. The alpha motor neuron of the agonist muscle is innervated to cause contraction, whilst the inhibitory neuron of the antagonist muscle in innervated to inhibit excitation of antagonist muscle's alpha motor neuron. Reciprocal inhibition is demonstrated in CRAC technique. By contracting the antagonist muscle, agonist muscle relaxes and allows an easier elongation of the muscle, thereby resulting in a greater ROM [16].

MET [17] is a direct and active manual technique involving isometric contraction to increase the ROM of a joint based on the principles of Golgi tendon organ and reciprocal inhibition. As mentioned before, GTO and reciprocal inhibition can be used to relax muscles, but in MET, the emphasis is placed more on increase ROM of the joint and not the muscles. MET requires the patient's muscle energy to resist a force by contraction, thereby initiating post-isometric relaxation and reciprocal inhibition to cause elongation of muscle fibres. Patient normally use less force for resisting movements in MET than PNF.

Effect of Stretching on the Range of Motion (including Neurophysiological Effects)

Stretching has been shown to increase the Range of Motion (ROM) due to a decrease in passive resistance, as a result of stretching over a period of time [18-20]. There are two contributing factors for this: the change in viscoelasticity and the neurophysiological changes, both as a result of stretching.

The change in elastic properties of a muscle-tendon unit causes the increased ROM, and it is the increased muscle compliance, rather than decreased muscle stiffness that is the causative factor behind this theory [21,22].

The change in elastic properties of a muscle-tendon unit causes the increased ROM, and it is the increased muscle compliance, rather than decreased muscle stiffness that is the causative factor behind this theory [21,22].

PNF is the main stretching technique behind the theory of neurophysiolocal changes from stretching. The four various mechanisms of PNF (autogenic inhibition, reciprocal inhibition, stress relaxation and gate control theory) causes an increase in electrical activity, allowing the neurophysiolocal changes to take place [23].

Effect of Stretching on Delayed Onset of Muscle Soreness (DOMS)

DOMS is the result of micro-injuries to muscle fibres, usually after excessive eccentric exercises, such as weight lifting [24]. This causes inflammation and swelling that causes pain in the muscle commonly 24-48 hours after the initial exercise. Stretching, although commonly used to reduce DOMS, has been shown to have no effect in reducing or preventing DOMS after intense exercises [20,25].

Objectives

P → Individuals who exercise on a regular basis

I → Pre-activity stretching (emphasis on Proprioceptive Neuromuscular Facilitation and Muscle Energy Techniques)

C → No pre-activity stretching

O→ Risk of injury

Methods

The methodology was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist [25].

Eligibility criteria

Peer-reviewed studies between 1998-2017, available in full English text were included. The exclusion of non-English articles is a limitation of this review. Studies examining the effect of stretching rather than flexibility are included, whilst the latter is excluded, due to stretching being an extrinsic factor on sports injury and flexibility considered as an intrinsic factor. In order to be comparable to the general population, participants must be healthy active individuals. Literatures stating the intensity, frequency and duration of the stretching interventions are included. Injury risk/prevalence must be assessed. Full inclusion criteria are listed.

Inclusion	Exclusion
Full-English Text	Case Reports
Randomised Controlled Trials	Reviews
Healthy individuals (including military)	Books
Control group	Conference Notes
Pre-activity stretching	Letters
Injury risk/prevalence assessed	Commentaries
	Habitual stretching
	Rehabilitation protocol

Table 1: Eligibility criteria.

Literature Search

The author (Tam. JPH) performed the data search and data extraction. This review is based on peer reviewed article published within the period 1998-2017. The search process began in March 2017, from which the title, main aims and MeSH terms were identified and refined. Thereafter, eligibility criteria were determined, and a formal literature search was performed by searching the following databases from inception with no added limits: Ovid MEDLINE 1946-Present, EMBASE 1974-2017, Cochrane Library, Web of Science. Search terms include 'sports', 'injury', 'stretch', 'warm up', 'muscle energy technique', 'proprioceptive neuromuscular facilitation'. Search strategies were created specifically for each database.

Duplicate records were discarded, after which titles and abstracts were individually screened. Literatures were excluded if the title was irrelevant or did not meet the eligibility criteria. Full text articles were obtained and reviewed for final inclusion/exclusion based on eligibility criteria.

Search Strategy

Ovid MEDLINE(R) 1946-present and EMBASE 1974-2017

1. Sports/ or Athletic Injuries/ or Sports Medicine/ or sport* injur*.mp.
2. stretch*.mp.
3. 1 and 2
4. muscle energy technique.mp.

5. proprioceptive neuromuscular facilitation.mp.
6. 1 and 5
7. warm up.mp.
8. 1 and 2 and 7

Web of Science

TOPIC: (stretch) and TOPIC: (sport) and TOPIC: (injury) CATEGORIES: (sport sciences or orthopedics) and publication years: 2000-2016.

Cochrane Library

Trials only

1. Stretch and injury *and* sport (11 trials)
2. Proprioceptive neuromuscular facilitation *and* injury (8 trials)
3. Muscle energy technique *and* injury (10 trials)

Search Results

Figure 1

Study Selection

The database search yielded 215 references. Most studies focused on the effect of stretching on sporting performance, range of motion rather than risk of injuries. Title and abstract screening resulted in 10 potentially eligible studies. After a detailed review of the potential 10 studies, only 5 fulfilled the inclusion criteria. Only 1 out of the 5 studies selected included PNF stretching in their protocol, the other 4 studies used static and dynamic stretches as intervention, there were no studies found to include MET in their protocol. This sequence of research was used for the other databases and resulted in a similar result.

Data Collection

Outcome Variable	Variable Definition
Injury Prevalence	Number of injuries sustained during the trial (excludes pre-existing injuries)
Types of injuries	Injury diagnosis as % of total injuries
Hazards Ratio	The number of times more likely (HR > 1) or less likely (HR < 1) an event is to happen in one group compared with another measured over time

Table 2: Outcome measures.

Quality Assessment

Methodological quality was assessed using the PEDro scale (Physiotherapy Evidence Database). PEDro is based on the Delphi list and the items are based on 'expert consensus' [26]. The reliability of PEDro is supported by various reviews of RCT assessment tools [27-29]. A total score out of 10 is derived for each study from the number of criteria that are satisfied. Each study was reviewed by the author (Tam. JPH) and an external medical professional. Each item was scored yes (+) if an item was met, no (-) if an item was not met, or unclear (?). For an objective quality score, total (+) scores were added up for each study the total score is determined by counting the number of criteria that are satisfied, except that scale item 1 is not used to generate the total score, so total scores are out of 10.

A PEDro score 6-10 is rated as 'high quality', score 4-5 as 'fair quality' and score ≤ 3 as 'poor quality' [30].

Results

*Column numbers correspond to the following criteria on the PEDro scale:

1. Eligibility criteria were specified
2. Subjects were randomly allocated to groups (or, in a cross-over study, subjects were randomly allocated an order in which treatments were received)
3. Allocation was concealed
4. Groups were similar at baseline
5. Subjects were blinded
6. Therapists who administered the treatment were blinded
7. Assessors were blinded
8. Measures of key outcomes were obtained from more than 85% of subjects
9. Data were analysed by intention to treat
10. Statistical comparisons between groups were conducted
11. Point measures and measures of variability were provided.

Table 3 presents the results of the methodological quality assessment using the PEDro scale for the included studies.

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Pope., *et al* [30].	+	+	?	?	-	-	-	-	?	+	+	3/10
Pope., *et al* [31].	+	+	?	+	-	-	+	+	+	+	+	7/10
Amako., *et al* [32].	+	+	-	-	-	-	-	-	-	+	+	3/10
Hadala., *et al* [33].	+	-	-	+	-	-	-	+	-	+	+	4/10
Jamtvedt., *et al* [34].	+	+	+	-	-	-	-	-	-	+	+	4/10

Table 3: Methodological quality assessment (PEDro) scale for the selected studies.

Table 4 provides an overview of the included studies, including the subjects investigated, types of stretching and stretching protocol used, main findings in relation to the effectiveness of the stretching programs.

Overall Injury Risks

All the studies reported injury prevalence and risks in both the intervention and control group. Pope.,., *et al*. [31]. Pope., *et al*. [32] and Jamtvedt., *et al*. [35] reported injury outcome as a hazard ratio, which describes the probability of an event (injury) happening in a treatment group (stretch) compared to a control group. Amako., *et al*. [33] reported it as a % of subjects injured in their corresponding group. Hadala., *et al*. [34] reported it as number of injured sailor per competition day.

Both Pope., *et al*. [31,32] assessed the effects of stretching on injury risks using new military recruits who then underwent 12 weeks of training. In Pope., *et al*. [31], the risk of soft tissue, bone and all other injuries were reported. In Pope., *et al*. [32], the risk of 6 specific leg injuries (Achilles tendonitis, lateral ankle sprains, stress fractures of foot and tibia, periostitis or anterior compartment syndrome) were reported. Although the hazard ratio in Pope., *et al*. [31] showed a reduction of injuries as a result of stretching, they reported that there is no conclusive evidence to support a correlation between pre-exercise stretching on jury risk due to the low statistical power(likelihood ratio 0.09). Pope., *et al*. [31] asses-

Study	Type of study	Intervention	Participants	Follow Up	Outcome	Statistical Measures
Pope., *et al*. [31]	Randomised Control Trial	Intervention: 2 20s static stretches for gastronomies and soleus Controls: 2 20s static stretches wrist flexors and triceps Both groups stretch before each activity session once every two days)	1093 17-35years old male recruit. 549 subjects in 26 intervention platoons and 544 subjects in 26 control platoons.	12 weeks (40 sessions)	23 lower limb injuries in intervention group and 25 lower limb injuries in control group	Hazard Ratio 0.92, 95% CI (0.52, 1.61)
Pope., *et al*. [32]	Randomised Control Trial	Intervention: 5min stretching programme (20s interspersed with 4min warm up) Stretches performed on 6 leg muscle groups Stretched before each activity session (once every two days) Controls: No stretch performed	1538 male recruits. 666 subjects in 19 intervention platoons and 702 subjects in 20 control platoons.	12 weeks (40 sessions)	158 lower limb injuries in intervention group and 175 lower limb injuries in control group	Overall Hazard Ratio 0.95, 95% CI (0.77–1.18) Soft-tissue Hazard Ratio 0.83, 95% CI (0.63–1.09) Bone injury Hazard Ratio 1.22, 95% CI (0.86 –1.76) 3.5 injuries per 1000 training days Univariate Cox regression model revealed no significant effect of stretching on all injuries. Likelihood ratio= 0.18 (p= 0.67)
Amako., *et al*. [33]	Randomised Control Trial	Intervention: 20-min supervised stretching (18 x 30s stretches) 12 stretches for hip flexors and quadriceps, 6 stretches for lower back and hamstrings after each training session Control: No stretch performed	518 subjects in intervention group and 383 subjects in control group.	2 years (1996-1998)	58 musculoskeletal disorders (MSD) in intervention group and 54 MSD in control group.	11.2% of intervention group developed MSD. 14.1% of control group developed MSD. (p=0.12)
Hadala., *et al*. [34]	Longitudinal Study	30mins stretching programme (12 different whole body static and PNF stretches), repeated twice daily and before competition	28 members (Yacht Crew)	4 Sailing seasons (cumulative intervention): 2004 (No intervention) 2005 (Stretching programme) 2006 (Physiotherapy and articular mobilisation) 2007 (Core stability programme and compressive clothing)	12 injuries in 2005 (Intervention Season). 33 injuries in 2004 (Control Season)	2004 (Control Season): 1.66 injured sailor per competition day 2005 (Intervention Season): 1.33 injured sailor per competition day ($p < 0.05$)
Jamtvedt., *et al*. [35]	Randomised Control Trial	30s stretches for 7 lower limb muscles interspersed for at least 14mins	2377 >18 years old subjects involved in ≥1 vigorous activity a week. 1079 subjects in intervention group and 1046 in control group.	12 weeks	339 injuries in intervention group and 348 in control group.	Overall Hazard Ratio: 0.97, 95% CI (0.84 to 1.13) (p = 0.69)

Table 4: Summary of selected studies.

	Muscle Injury	Joint Injury	Tendon Injury	Bone Injury
Pope., *et al.* [30]	Not reported.	11 ankle sprains reported in intervention group. 16 ankle sprains reported in control group.	1 Achilles tendonitis reported in intervention group. 0 reported in control group.	4 tibia stress fractures, 4 foot stress fracture, 2 tibia periostitis reported in intervention group. 8 tibia stress fractures reported in control group.
Pope., at al. [31] (Compartment syndrome, bursitis was recorded, but not included in this table)	14 lower limb injuries reported in intervention group. 21 reported in control group.	27 patellofemoral joint injury reported in intervention group. 40 reported in control group.	20 lower limb tendinopathy reported in intervention group. 17 reported in control group.	64 lower limb injury reported in intervention group. 55 reported in control group.
Amako., *et al.* [32]	2.5% of the intervention group reported muscle and tendinopathy (grouped together in as 1 outcome variable). 6.9% reported in control group.	1.4% of the intervention group reported joint injuries. 1.6% in reported control group. 2.5% of the intervention group reported ligament injuries. 3.1% reported control group.	See muscle injury.	1% of the intervention group reported lower back pain. 3.5% reported in control group.
Hadala., *et al.* [33]	22 injuries in 2004 season. 4 injuries in 2005 season.	1 injury in 2004 season. 4 injuries in 2005 season.	22 injuries in 2004 season. 4 injuries in 2005 season.	Not reported.
	Muscle, ligament and tendon injuries	**Bothersome soreness (Average experienced during a week)**		
Jamtvedt., *et al.* [34]	133 per 1000 subjects (intervention group), 177 per 1000 subjects (control group) HR 0.75 (0.59 to 0.96) p = 0.03	246 per 1000 subjects (intervention group), 323 per 1000 subjects (control group) OR 0.69 (0.59 to 0.82)		

Table 5: Results categorised by type of injuries.

sed the effect of ankle dorsiflexion flexibility on injury as well. They found a statistically significant relationship between reduced flexion and injury risk. A higher number of ankle sprains were sustained by ankles which had a reduced range of motion. However, this relationship was not apparent with stress fractures.

low statistical power(likelihood ratio 0.09). Pope., *et al.* [31] assessed the effect of ankle dorsiflexion flexibility on injury as well. They found a statistically significant relationship between reduced flexion and injury risk. A higher number of ankle sprains were sustained by ankles which had a reduced range of motion. However, this relationship was not apparent with stress fractures.

A univariate Cox regression analysis showed no significant effect of stretching on injury risk in Pope., *et al.* [32]. In their study, they collected data on subjects' height, weight and a 20 metre shuttle run test score. When they did a multivariate model on injury risk, they found no significant effect of height nor weight on injury risk. Interestingly, they found that a fitter subject (as rated by a 20 metre shuttle run test score) were 14 times less likely to sustain a lower limb injury. Of the muscle strains reported (14 in stretching group, 21 in control group), 2 were thigh strains in the stretching group, compared to 10 in the control group, and this was statistically significant ($p < 0.05$).

In Amako., *et al.* [33], most injuries were lower back muscle strains with some tendinopathy reported, but no differences in bone injury. There were 11 lower limb muscle strains and 12 lower back muscle strains across both groups (7 in stretching group and 16 in control group), this shows a significantly lower incidence of injury in the stretch group ($p < 0.05$). The intervention group showed a 67% reduction in strains and tendinopathies. Although there were some differences in injury risks between both groups, statistical power wasn't strong. The author attributed the decrease in muscle strains and tendinopathy due to the increase in ROM as a result of stretching. Amako., *et al.* [33], like the rest of the studies included in this review, supported that stretching had no effect on bone injuries.

Hadala., *et al.* [34] recruited a yachting crew of 28 sailors from the America's Cup competition and implemented a new intervention each season, beginning in 2004 as the control season and ending in 2007. In 2004, the crew only did their traditional warm-up regime before competition with no stretching. Over the next 3 years, stretching (both PNF and static), preventative taping, articular mobilisation, post-exercise ice bathing were introduced to the team progressively. In the control season, there was 1.66 injured sailors per competition day, and this decreased to 0.60 in 2007. As each season progressed, a new intervention was added (physiotherapy in 2006, articular mobilisation + ice bath in 2007), and this reduced injury risks even more. Between the control season and end-season (2008), an 82% reduction in injuries was reported. Injuries were categorised into body areas. There was a significant decrease in shoulder and cervical spine injury (0.73 in 2004, 0.2 in 2005), a slight decrease in lumbar spine, elbow and wrist injury without statistical significance, and a minor increase in knee injuries. Hadala., *et al.* [34] found articular injuries increased progressively through the 4 seasons but didn't comment whether they were traumatic injuries or sport injuries.

Jamtvedt., *et al.* [35] recruited a large cohort of the general population using the internet, emails and promotion programmes. Subjects were randomly allocated to either the intervention or control group. They were asked to provide an online feedback each week asking whether they sustained an injury, and if so, the location and type of the injury. The incidence rate for injuries across both groups was 2.41 per person-years, 0.77 per person-years for muscle injuries and 0.36 per person-years for tendinopathy. Stretching didn't have a statistically significant effect on injury risk, but it did reduce 'bothersome soreness'. Risk of 'bothersome soreness' was 24.2% in stretch group and 32.2% in control group. Interestingly, they found a significant interaction between age and effect of stretching on injury risk. Hazard ratio was 0.75 (95% CI 0.56-0.995) in 20-yearolds, 0.97 (95% CI 0.84-1.13) in 40-year-olds and 1.26 (95% CI 0.94-1.68) in 60-year-olds.

Risk of Bias

This review used a systematic review methodology to eliminate as many bias as possible and selected literatures which matched the eligibility criteria. Only trials published in English were selected, therefore, there is a possibility of other eligible trials, causing potential publication bias.

In Pope., *et al.* [31], 162 subjects (98 from intervention group, 64 from control group), out of a total of 1093 subjects, were discharged before the completion of programme. Furthermore, 48 subjects from the control group withdrew from the study. Data were not available for this cohort of subjects. A survival analysis was performed to minimise the loss to follow up bias caused by the withdrawal of subjects. Recruits who had to leave from the programme had their survival censored, therefore, only the time spent up until the time of their withdrawal was analysed. This method of statistical analysis enhances the accuracy data because it accounts for the time the recruits were at risk of injury, and not across the whole 12 weeks of training.

There was a similar issue in Pope., *et al.* [32]. 170 subjects (69 from intervention group, 101 from control group), out of a total of 1538 subjects, were discharged before the completion of programme. Although they didn't finish the programme, their data was still included in the overall analysis by correlating their injury risk with the number of days they were at risk, therefore, this censoring effect is unlikely to be a confounder.

In this review, subjects from the trials were often not recruited from the general population due to the difficulty in organising a large cohort of lay population and the inability to supervise stretching strictly. Pope., *et al*. [31,32] and Amako., *et al*. [33] used military recruits, thus making this a cluster RCT. Hadala., *et al.* [34] recruited an elite crew of rowers for their longitudinal study. This creates selection bias because it is likely military recruits and elite rowers are healthier at baseline compared to the general population and thus, they could be less at risk of injury due to the their intrinsic fitness level. In addition, the authors didn't adjust their statistical analysis for clustering effects.

Jamtvedt., *et al.* [35] recruited a large cohort of the general population via the internet, although their result could relate to the general population more than the other trials in this review, Jamtvedt., *et al.* [35] still presented some flaws in their methodology. 75.9% of their participants provided data on injury reports and no intention to treat analysis was used to minimise loss to follow up bias. The author, however, argued that there is minimal loss to follow up bias because stretching appeared to reduce soreness (their other outcome variable) in the first week with little loss to follow up, and this effect remained constant thereafter. Participants reported their injury and soreness status via the internet, this induces a discrepancy between different subject's personal perception of what injury and soreness is. Reports of injuries may therefore be over or under reported.

Discussion

This review covered literatures examining the relationship between stretching and injury risks. The author believes the strict eligibility criteria ensured only the most recent and valid trials were reviewed. The studies in this review showed conflicting results, highlighting the need for future trials on this topic.

Difference in Participants

Pope., *et al.* [31,32] both concluded that pre-activity stretching had no effect on injury risk. Most of the injuries accounted for were overuse injuries, thus stretching has no effect on overuse injury, which could've been confounded by factors such age, genetics, anatomy, training hours, all of which were not controlled for in the studies. Jamtvedt., *et al*. [35] also found stretching didn't have a clinically significant effect on overall injury risk but did reduce 'bothersome soreness'. On the other hand, Amako., *et al.* [33] showed static stretching was protective against muscle and tendon related injuries, but not bone injuries. Hadala., *et al.* [34] used a combination of PNF and static stretching and also showed a positive decrease in overall injury risks.

Difference in stretching protocol

The intervention protocol varied in types of stretching, frequency, intensity and body areas across all the studies in this review. Amako., *et al.* [33] and Hadala., *et al*. [34] used a 20mins and 30mons stretching protocol respectively for their intervention group, these two trials had the longest stretching protocol out of all 5 studies reviewed and were the only 2 trials to conclude a beneficial effect of stretching on injury risk, so this creates a hypothesis on whether the duration of stretching alone has an influence on injury risk. It would be interesting to assess whether stretching over a prolonged period of time (months or years), or increased frequency of stretching would produce a statistically significant reduction in injury risks.

Difference in Methodology

Of all the studies reviewed, perhaps Jamtvedt., *et al.* [35] had the most interesting methodology. It required participants to consistently report data accurately via an online questionnaire. There are disadvantages to this approach as it causes reporting bias and loss to follow up bias as mentioned before. However, an internet based trial is able to recruit a large and diverse cohort from lay population, which would've been difficult to do using a standalone RCT methodology. It increases the applicability of the findings to the general population, in comparison to the other studies who recruited militants and rowing crew.

Recommendation for Future Trials

The variation in definition of injury, methodology, study population and outcome measures in published trials on this subject makes it challenging to compare the trials against each other and to determine a valid conclusion. In the future, there is a need of an RCT trial recruiting members of the general population who are relatively similar in demographics at baseline, to undergo a supervised stretching programme over a prolonged period of time (at least months) and to monitor their injuries which could be grouped by the body area and body structure. Ideally, participants will be randomly allocated to different groups. There must be a control group who don't stretch, and intervention groups who stretch using different techniques (static, dynamic, PNF). Ideally, the assessors will be blinded as well, and the participants will be monitored uniformly to assess their compliancy with the intervention. In statistical analysis, assessors should consider calculating the risk of injuries as a risk of injury per hours of physical activity participation, rather than injury prevalence over time.

Limitations

The findings from literatures cited in this project didn't provide a clear yes/no answer to whether stretching is beneficial in preventing injuries. There are a few reasons as to why this was. It is extremely difficult to control all the confounding factors which may contribute towards likelihood of sustaining an injury. Participants have different physical and mental attributes, leading to different levels of body compliance when doing physical activities, thereby inducing different levels of injury risks.

Definition of injury

In Pope., *et al.* [31,32] subjects were considered injured if they were unable to return to full duties without signs or symptoms in three days. In Hadala*., et al*. [34], injury was defined according to Bahr*., et al.* [36] as ''any acute trauma or repetitive stress associated with athletic activities during sailing or training causing pain, dysfunction, pathology or disability and resulted in at least one treatment from the crew's medical staff.'' Both Amako., *et al.* [33] and Jamtvedt., *et al.* [35] didn't provide a clear definition of 'injury'. Evidently, the definition of injury varied across the studies, therefore, what one study might consider as an injury, another study might not, thus lead to an over or under estimation of prevalence of injuries.

Compliance of stretching and physical activities

The supervision of stretching protocol, compliance of subjects to follow their intervention and levels of physical activities are all difficult aspects to control, and this was evident across all the studies in this review. In Pope., *et al*. [32], 5% of the control group actually stretched alongside their warm up and 32% of the intervention group didn't do their proposed warm-up even though they followed the stretching programme. Pope., *et al.* [31,32] concluded that whilst compliance is a big confounding factor to the results, it would still be easier to control compliance in a military setting because of the nature of military practice and supervision provided by commanders. In Amako., *et al.* [33], the control group still stretched for 5-10min prior to each training session, whilst the stretching group had 20minutes of supervised dynamic stretches. There was no mention on how they were supervised and whether the 2 groups had followed the same training regime and intensity. In Hadala., *et al.* [34], due to the subjects being in an elite sports setting, compliance and levels of activity were much easier to control. The entire injury prevention programme across the 4 seasons were monitored by a team of physiotherapists and team doctors. The methodology of Jamtvedt., *et al*. [35] induced issues with compliancy and follow up of data because the subjects were essentially their own assessors. Instructions of their stretching protocol were given via internet, rather than being delivered and assessed by a trained professional. Levels of non-compliancy varied between the 2 groups (0.9% in stretching group and 6.3% in control). This imbalance of non-compliancy between the 2 groups reduces the reliability and validity of data. There was more non-compliancy in the control group, and this could be explained by the common belief of including pre-activity stretching as part of a pre-activity warm up. Some subgroups may also benefit by being more compliant with their stretching programme or by the type of their physical activity.

Conclusion

This review assessed and collated published trials on the use of stretching in injury prevention. However, the results were varied as shown above. Currently, there is no conclusive evidence to recommend stretching or no stretching as a tool to reduce injury risk.

Further research should not focus solely on stretch or no stretch, but also different aspects of stretching such as types, intensity, duration. It would be interesting to compare the effect of stretching in lay population against established athletes, and also the intensity of physical activity post-stretching.

Summary Box

- Stretching is shown to reduce overuse injuries in militants and elite athletes.
- Stretching is shown to reduce ‘bothersome soreness’ in the general population.
- There is no conclusive evidence to approve and disapprove the use of stretching in injury prevention.
- Range of Motion appears to have an effect on likelihood of sustaining an injury.
- The frequency, intensity and duration of stretching could all have an effect on risk of sustaining an injury.

Competing Interests

The authors have no professional relationships with companies or manufacturers who might benefit from the results of the study.

Contributor Ship

Tam. JPH designed, researched, carried out data extraction, analysed, and completed the write up of this systematic review.

Acknowledgements

Tam. JPH would like to thank University of Bristol Medical School for providing online resources during this project.

Bibliography

1. HSE: Statistics on Obesity, Physical Activity and Diet: Health Survey England, Health and Social Care Information Centre (2012).
2. Cabbie BJ., *et al*. “Predictors of hamstring injury in the elite level of Australian football”. *Scandinavian Journal of Sports Medicine* 16 (2006): 7-13.
3. Brukner P and Khan K. “Clinical Sports Medicine”. Sydney, McGraw Hill. (1993): 372-391.
4. Hartig DE and Henderson JM. “Increasing hamstrings flexibility decreases lower extremity overuse injuries in Military Basic Trainees”. *American Journal of Sports Medicine* 27.2 (1999): 173-176.
5. Witvrouw E., *et al*. “Intrinsic risk factors for the development of patellar tendinitis in an athletic population: a two years prospective study”. *American Journal of Sports Medicine* 29.2 (2001): 190.
6. Witvrouw E., *et al*. “Muscle flexibility as a risk factor of developing muscle injuries in professional male soccer players”. *American Journal of Sports Medicine* 31.1 (2003): 41-46.
7. Shrier I. “Stretching before exercises does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature”. *Clinical Journal of Sport Medicine* 9 (1999): 221-227.
8. Weldon SM and Hill RH. “The efficacy of stretching for prevention of exercise-related injury: a systematic review of the literature”. *Manual Therapy* 8 (2003): 141-150.
9. Kay AD and Blazevich AJ. “Effect of acute static stretch on maximal muscle performance: a systematic review”. *Medicine and Science in Sports and Exercise* 44 (2012): 154-164.

10. Jones BH and Knapik JJ. “Physical training and exercise related injuries. Surveillance, research and injury prevention in military populations”. *Sports Medicine* 27 (1999): 111-125.

11. Wilson GJ., *et al*. “The relationship between stiffness of the musculature and static flexibility: an alternative explanation for the occurrence of muscular injury”. *International Journal of Sports Medicine* 12 (1991): 403-407.

12. Paradisis GP., *et al*. “Effects of static and dynamic stretching on sprint and jump performance in boys and girls”. *The Journal of Strength and Conditioning Research* 28 (2014): 154-160.

13. Levine MG and Kabat H. “Proprioceptive facilitation of voluntary motion in man”. *The Journal of Nervous and Mental Disease* 117.3 (1953): 199-211.

14. Funk DC., *et al*. “Impact of Prior Exercise on Hamstring Flexibility: A Comparison of Proprioceptive Neuromuscular Facilitation and Static Stretching”. *National Strength and Conditioning Association Journal* 17.3 (2003): 489-492.

15. Sharman M., *et al*. “Proprioceptive Neuromuscular Facilitation Stretching: Mechanisms and Clinical Implications”. *Sport Medicine* 36.11 (2006): 929-939.

16. Rowlands AV., *et al*. “Chronic flexibility gains: effect of isometric contraction duration during proprioceptive neuromuscular facilitation stretching techniques”. *Research Quarterly for Exercise and Sport* 74.1 (2003): 47-51.

17. Chaitow L. “Muscle energy techniques”. Elsevier Health Sciences, (2006).

18. McHugh MP and Nesse M. “Effect of stretching on strength loss and pain after eccentric exercise”. *Medical Science and Sports Exercise* 40.3 (2008): 566-573.

19. Ryan ED., *et al*. “The time course of musculotendinous stiffness responses following different durations of passive stretching”. *Journal of Orthopaedic and Sports Physical Therapy* 38 (2008a): 632-639.

20. Tanigawa MC. “Comparison of the hold-relax procedure and passive mobilization on increasing muscle length”. *Physical Therapy* 52 (1972): 725-735.

21. Toft E., *et al*. “Passive tension of the ankle before and after stretching”. *American Journal of Sports Medicine* 17 (1989): 489-494.

22. Bandy WD., *et al*. “The effect of time and frequency of static stretching on flexibility of the hamstring muscles”. *Physical Therapy* 77 (1997): 1090-1096.

23. Osternig LR., *et al*. “Muscle activation during proprioceptive neuromuscular facilitation (PNF) stretching techniques”. *American Journal of Physical Medicine* 66 (1987): 298-307.

24. Connolly DA., *et al*. “Treatment and prevention of delayed onset muscle soreness”. *The Journal of Strength and Conditioning Research* 17 (2003): 197-208.

25. Moher D., *et al*. “Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement”. *Journal of Clinical Epidemiology* 62.10 (2009): 1006-1012.

26. Verhagen AP., *et al*. “The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus”. *Journal of Clinical Epidemiology* 51 (1998): 12351241.

27. Moseley AM., *et al*. “Reliability of a scale for measuring the methodological quality of clinical trials”. Proceedings of the Cochrane colloquium. Rome, Italy: Cochrane Centre, (1999): 39.

28. Maher CG., *et al*. “Reliability of the PEDro scale for rating quality of randomized controlled trials”. *Physical Therapy* 83 (2003): 713-721.

29. de Morton NA. “The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study”. *Australian Journal of Physiotherapy* 55.2 (2009): 129-133.

30. https://www.pedro.org.au/wp-content/uploads/PEDro_scale.pdf

31. Pope R., *et al*. “Effects of ankle dorsiflexion range and pre-exercise calf muscle stretching on injury risk in Army recruits”. *Australian Journal of Physiotherapy* 44.3 (1998): 165-172.

32. Pope RP., *et al*. “A randomized trial of preexercise stretching for prevention of lower-limb injury”. *Medicine and Science in Sports and Exercise* 32 (2000): 271-277.

33. Amako M., *et al*. “Effect of static stretching on prevention of injuries for military recruits”. *Military Medicine* 168 (2003): 442-446.

34. Hadala M and Barrios C. “Different strategies for sports injury prevention in an America’s Cup Yachting Crew”. *Medicine and Science in Sports and Exercise* 41 (2009): 1587-1596.

35. Jamtvedt G., *et al*. “A pragmatic randomised trial of stretching before and after physical activity to prevent injury and soreness”. *British Journal of Sports Medicine* 44.14 (2010): 1002-1009.

36. Bahr R and Maehlum S. “Clinical Guide to Sports Injuries”. Champaign (IL): Human Kinetics Publishers (2003): 3-22.

Volume 2 Issue 2 February 2019