

# EFFECTS OF STRETCHING IN PREVENTING SPORTS INJURIES: A SYSTEMATIC REVIEW

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## Abstract

**Introduction** – Prevention programmes have been shown to have a positive effect on prevention of injury, however, stretching has limited evidence of effectiveness in preventing injury. This systematic review was undertaken to examine the evidence that stretching prevention protocol has demonstrated effectiveness as a means of reducing SRIs.

**Method** – Three electronic databases were searched by two reviewers to identify randomised and controlled clinical trials comparing the effectiveness of stretching to either a different intervention or a control group. Studies measuring the rate of injury were included. When an article met the inclusion criteria, it was appraised using the PEDro scale.

**Result** – There were nine moderate-to-high quality trial studies which met the inclusion criteria. These studies contained athletes participants, from recreational to semi-professional level, in various sports. Stretching intervention was compared to either eccentric or strength or stabilisation or control group. Some studies showed significant decrease of injury whereas others did not. To enhance understanding of this phenomenon, different confounder factors were described, namely stretching duration, stretching frequency, stretching timing, the rate of overall and specific injuries and, the rate of acute and overuse injuries.

**Conclusion** – The results support the hypothesis that stretching prevention protocol was effective in reducing sport-related acute injuries but not overall injury rate. Further research is required to confirm this hypothesis.

*Keywords* : Prevention, stretching, sport, injuries, systematic review.

## Introduction

In Europe, about 40% of people participate in at least one form of physical exercise (PE) each week (1). Health and fitness improvement is participants' main motivation. The positive effects on the immune system (2) and mental health (3) are increasingly associated with regular PE. However, as more people participate in PE, about 4.5 million Europeans aged 15 years old and older are hospitalised because of a sports-related injury (SRI) per year (4). Moreover, about 10% of general practitioners' referrals for physical therapy are related to SRIs (5). In economic terms, the direct insurance costs for SRIs represent 0.08% of the healthcare budget, whereas indirect costs, such as absenteeism, represent 3.4% (6). To prevent SRIs, an injury prevention strategy could thus be beneficial for both athletes and society.

Based on meta-analysis of randomised controlled trials (RCTs) and systematic reviews (SRs), prevention programmes have been shown to have a positive effect on SRIs (7-12). In these studies, different methods have been examined: proprioception, eccentric, strength, multicomponent, exercise therapy and warm-up sports-specific exercises. All these preventive approaches significantly decrease the rate of SRIs. (7-12) However, there is debate about the effectiveness of stretching as part of prevention programmes to reduce SRIs.

Some authors claim that stretching routines before and after PE show no significant or no conclusive reduction in SRIs (13-18). In these articles, the effect of stretching is questioned and hypothesised a negative effect of stretching on sports performance (15, 18) or even on muscle tissue (14-16). Nonetheless, others articles state that stretching affects flexibility and range of motion, which could have a positive effect on SRI prevention (14, 18). The compliance of the muscle/tendon unit seems to be the key factor in determining the effectiveness of stretching prevention programmes. Indeed, the relationship between the compliance of the muscle/tendon unit and SRI is likely to be sports-dependent (14, 17, 18). The type of stretching used might also be of importance : passive, static, isometric, ballistic and proprioceptive neuromuscular facilitation (PNF) have unique characteristics (13) that affect physiological muscles/tendons differently and therefore in their preventive action.

Given the importance of reducing SRIs for both athletes and society, this systematic review aims to determine whether stretching is an effective tool for the prevention of SRIs in athletes. The hypothesis is that stretching prevention protocol is effective whether the purpose of stretching is sport-dependent. Published RCTs and CCT will be used to answer the research question.

## Method

### Definition of Injury

In literature, definitions of sports injury can vary from one article to another, depending on the sport studied. In accordance with Orchard et al (19), we claimed that an injury can be classified into two categories :

- « General time loss » injuries, that could prevent player from taking part in training or games, without taking into account the fact that a match/training is planned
- « Medical attention » injuries, that requires medical or paramedical attention and may affect a training. This definition therefore includes injuries requiring or not stopping sport activity.

### Design

This systematic review was based on the guidelines established by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (20). The study was not registered.

### Search Method

One researcher (D.B.) looked for eligible studies in order to conduct a literature search. The following databases were used : PubMed, PEDro and Cochrane Library. Four main concepts were applied during the research (injury, prevention, stretching and sport).

For PubMed, MeSH Terms were used :

#1 (Concept 1) : injury OR sport injury OR athletic injury OR sport accident OR sport trauma

#2 (Concept 2) : Sport OR athlete OR sportsman OR sportswoman OR physical activity OR physical exercise OR team sport OR exercise

#3 (Concept 3) : prevention OR injury prevention OR preparation OR injury prevention program

#4 (Concept 4) : stretching OR passive stretching OR active stretching OR PNF stretching OR stretching exercise OR flexibility OR stretching program

Consequently, the main keywords were as follows : #1 AND #2 AND #3 AND #4

(((((injur\*) OR sport injur\*) OR athlet\* injur\*) OR sport accident) OR sport trauma) AND (((((((Sport) OR athlet\*) OR sportsman) OR sportswoman) OR physical activit\*) OR physical exercise) OR team sport) OR exercise) AND (((prevent\*) OR injur\* prevent\*) OR preparation) OR injur\* prevent\* program) AND (((((((stretch\*) OR passive stretch\*) OR active stretch\*) OR PNF stretch\*) OR stretch\* exercise) OR flexibility) OR stretch\* program)

For Cochrane Library, search terms were as the ones for PubMed.

For PEDro, advanced search for articles was used : (injur\* sport\* prevent\* stretch\*)

References from selected articles were also checked to find any relevant studies that could have missed in the literature search.

## **Inclusion Criteria**

- *Type of Research Design*

Studies were assessed according to the PEDro scale, which is based on a Delphi list (21). This scale allows us to rate and classify articles (low = 0 to 3 points, moderate = 4 to 7 points, high = 7 to 10 points). In our review, only moderate and high quality articles were included.

Studies that were RCTs or controlled clinical trials (CCTs), issued in print or online were included. Moreover, articles had to be published in either English or French, between January 2000 and September 2018.

- *Intervention Programmes*

The treatment exposure involves stretching programme including different kinds of approaches: static stretching, dynamic stretching, and PNF stretching. The intervention setting was dependent on the studies. Prevention programmes contained a particular stretching component, while studies with multicomponent exercise interventions were excluded. Studies examining the effects of stretching on the rate of injury were thus included in the review.

- *Participants*

Studies were eligible if they investigated men and women of all ages engaged in team sports, at any level (recreational, semi-professional or professional). As a result, the type of population is wide, with musculotendinous and osteo-articular constraints.

- *Outcome Measure*

The rate, ratio or total number of injuries was our primary outcome measure : injury rate ratio = (injury rate intervention groupe / hours of exposure) / (injury rate group control / hours of exposure).

## **Data Collection and Extraction**

- *Inclusion Procedure*

One researcher (D.B.) screened the titles and abstracts of the articles found from the literature search to determine potential eligibility and relevance. At the end of this selection, a second researcher (J.M.C.) screened the selected articles to ensure the inclusion criteria were met. After this cross-checking, a final consensus was obtained following PRISMA recommendations (20).

- *Data Extraction*

Characteristics associated with background information (author name, year), study data (number of participants, age, level of sports, sex, team sport type), and intervention/group control (stretching prevention programme type, stretching approach, frequency, duration) were gathered. The main outcome measure was the rate, ratio or total number of injuries. Significant outcomes resulted in the reduction of SRIs with a P value < 0.05 or a 95% confidence interval. If relevant for the review, other significant outcomes would be included.

### **Methodological Quality Evaluation**

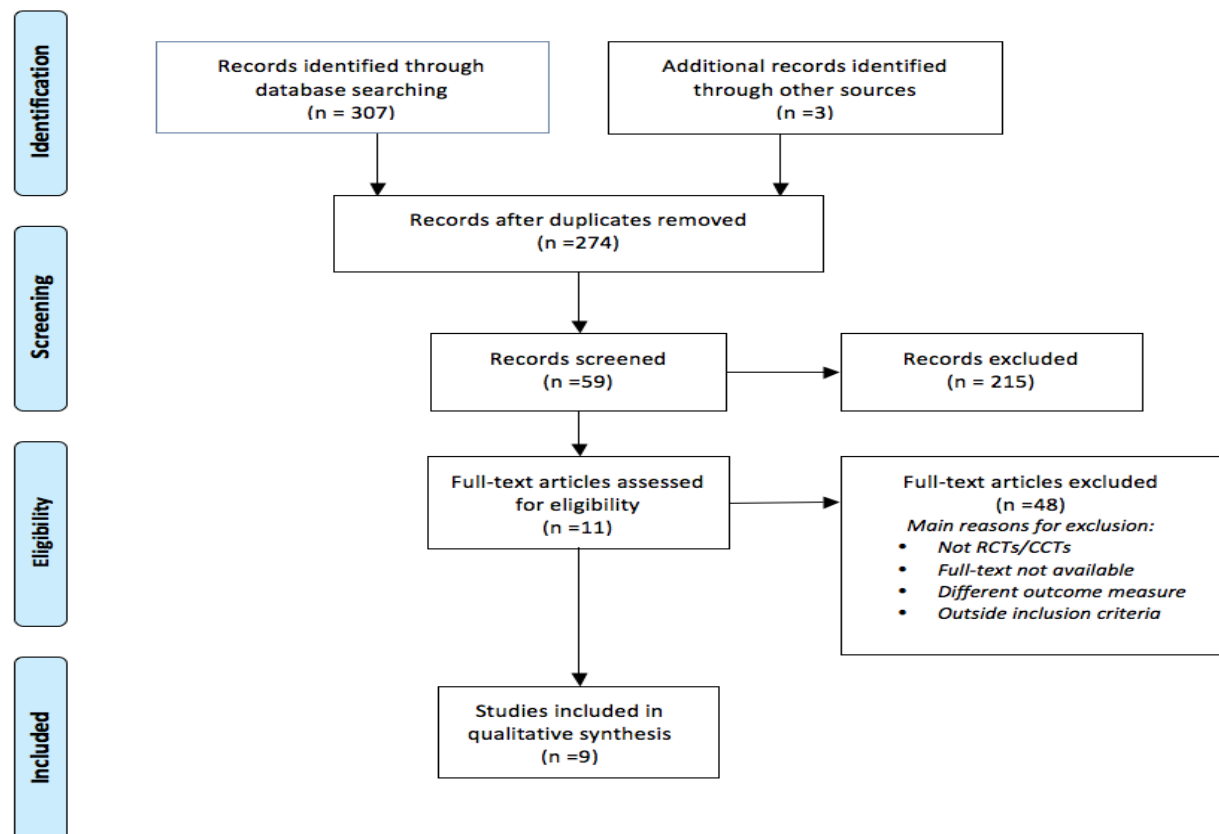
One researcher (D.B.) scored the methodological quality of the articles chosen using criteria from the PEDro scale. This is a reliable and valid tool for assessing study quality (21). Items were scored as follows: yes = 1 point ; no / cannot answer / not applicable = 0 points. Studies were considered to be « high quality » if they scored 7 to 10 points, « moderate quality » if they scored 4 to 7 points, and « low quality » if they scored 0 to 3 points. If the researcher was uncertain about a particular criterion, J.M.C. was consulted. The final decision was made by D.B.

## **Results**

### **Identification of studies**

The search for articles resulted in 307 relevant studies from the selected databases. We added three studies identified through the references. After removing duplicates and screening the titles and abstracts, 59 articles remained eligible. The assessment of full texts reduced this number to nine articles. Articles were excluded if they did not meet the inclusion criteria, such as multicomponent intervention (stretching combined with multiple exercises), population (factory worker, professional yachting), and study design (longitudinal, cohort, retrospective). One article met all criteria but was excluded as no full text was available. The selection procedure is displayed **Figure 1**.

Consequently, the final number of 9 studies were included: Shitara et al. (2017) [22]; Baltich et al. (2016) [23]; Bello et al. (2011) [24]; Jamtvedt et al. (2010) [25]; Liu et al. (2008) [26]; Fredberg et al. (2008) [27] ; Gabbe et al. (2006) [28] ; Amako et al. (2003) [29] ; Pope et al. (2000) [30].



**Figure 1** – Flow chart of study identification procedure.

### **Study Characteristics**

Eight of these studies are RCTs and one is a controlled clinical study (CCT). All studies investigate the effect of specific stretching protocols over at least 12 weeks. A total of 5635 participants were involved. Two studies were interested in the military, three studies focused on soccer players, one on recreational runners, one on baseball players and two on subjects carrying out regular PE. All RCTs include a significant number of subjects (92 subjects minimum). The stretching protocols differ from one article to another (from stretched muscles to stretch duration). Besides these various protocols, the timing of execution differed ; four studies analysed the effect of stretching after exercise, two before exercise, two before and after exercise and one at various times of the day (breakfast, lunch and dinner). **Table 1** describes their main characteristics.

### **Methodological Quality**

**Table 2** summarises the methodological quality of the studies. The scores ranged from 4-7 out of 10 (mean 5.1). These studies are all conform to the inclusion criteria which excluded articles lower than 4. Seven articles were « moderate quality » while two were « high quality ». In some cases, the assessors were not able to score all criteria on the PEDro scale, as some articles did not clearly specify their method design (criteria 2 to 7) and/or data (criteria 8 to 11). None of the study interventions blinded the participants or therapists, which is unavoidable under such a protocol design.



**Table 2 - Scores on PEDro Scale (21)**

| <i>Study</i>           | <i>Outcome</i> | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> | <b>9</b> | <b>10</b> | <b>11</b> | <b>Total Score</b> |
|------------------------|----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|--------------------|
| <b>Shitara et al.</b>  | Injury         | +        | -        | -        | +        | -        | -        | -        | +        | +        | +         | -         | 4/10               |
| <b>Baltich et al.</b>  | Injury         | +        | +        | +        | +        | -        | -        | -        | ?        | +        | -         | -         | 4/10               |
| <b>Bello et al.</b>    | Injury         | +        | +        | ?        | +        | -        | -        | -        | ?        | -        | +         | +         | 4/10               |
| <b>Jamtvedt et al.</b> | Injury         | +        | +        | +        | +        | -        | -        | -        | +        | +        | +         | +         | 7/10               |
| <b>Fredberg et al.</b> | Injury         | +        | +        | -        | +        | -        | -        | -        | ?        | -        | +         | +         | 4/10               |
| <b>Liu et al.</b>      | Injury         | +        | +        | -        | +        | -        | -        | -        | +        | +        | +         | +         | 6/10               |
| <b>Gabbe et al.</b>    | Injury         | +        | +        | +        | +        | -        | -        | -        | ?        | +        | +         | +         | 6/10               |
| <b>Amako et al.</b>    | Injury         | +        | +        | ?        | +        | -        | -        | -        | ?        | -        | +         | +         | 4/10               |
| <b>Pope et al.</b>     | Injury         | +        | +        | ?        | +        | -        | -        | +        | +        | +        | +         | +         | 7/10               |

1- Eligibility criteria were specified

2- Subjects were randomly allocated to groups

3- Allocation was concealed

4- The groups were similar at baseline regarding the prognostic indicators

5- There was blinding of all subjects

6- There was blinding of all therapists who administered the therapy

7- There was blinding of all assessors who measured at least one key outcome

8- Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups

9- Data for at least one key outcome was analysed by « intention to treat »

10- The results of between-group statistical comparisons are reported for at least one key outcome

11- The study provides both point measures and measures of variability for at least one key outcome

### **Description of the Results**

One randomised study concluded that static stretching is ineffective at preventing lower limb injuries (30). Two randomised studies did not show any significant differences in the overall risk of lower limb injuries, but nevertheless showed a significant decrease in tendon/muscle lesions (25, 29) and lower back injury (29) in the stretching group ( $p=0.03$  and  $p<0.05$ , respectively). Two randomised studies showed a significant decrease in the risk of injury to shoulder (22) and lower extremities (27) (odd ratio : 0.44 and 0.47, respectively).

When comparing stretching with other prophylactic training, the studies did not show a significant difference in the rate of injury. In fact, the CCT study showed no significant decrease in lower limb injury between rhythmic stabilisation and stretching intervention (24). The same conclusion held for eccentric training versus stretching (28) and strength training versus stretching (22, 23). One randomised study showed that stretching combined with eccentric exercise significantly reduces the frequency of abnormalities in the patellar tendon ( $p=0.02$ ) but not in the Achilles tendon. Further, in Achilles tendon programme, it does not reduce risk of injury ; on the contrary, it may increase in some cases ( $p=0.04$ ) (26).

**Table 3** describes the outcome of the studies. Jamtvedt et al. (25) disclosed a significant interaction between age and stretching effect on the risk of injury ( $p=0.039$ ). This study showed that the effects of stretching in injury prevention seem to be more beneficial for younger adults than for older adults. The authors demanded interpreting these results with caution, without neglecting possible confounder interactions. Amako et al. (29) noted the tendency for stress fracture and overuse shin splints in the stretching group. While these

outcomes are not significant, the authors called for further research in that direction. The odd ratios of all studies are given **Table 4**.

The design factors differed from one study to another. We summarise the key results according to the five confounding factors below.

- Type of sports activity (overuse vs. acute injury)

The review included five kinds of sports activity. Overuse injuries are related to endurance sports or military trainings that do not involve sprint, explosive-type movement. Of the five studies involving endurance activities (23, 25, 26, 29, 30), only one showed a benefit of stretching, with the overall injury rate being the common outcome. Of the four studies involving sprint-type sports (22, 24, 27, 28), two showed benefits with fewer muscle/ligaments injuries.

- Stretching duration (short vs. long)

Five studies utilized a stretching protocol lasting more than five minutes (23, 25, 27-29). Of these, two showed a significant result of stretching as preventing injuries. Three studies suggested a stretching protocol lasting less than or equal to five minutes (22, 26, 30). Of these, two showed some benefits of stretching. However, they imposed stretching on a single muscle group (internal rotators shoulder or calves). Proportionally to the other studies, which discussed stretching multiple muscle groups (up to seven), it seems like they spend the same amount of time per group muscle. One exception was Pope et al. (30), who included five muscle groups in less than four minutes (meaning a 20-second stretch per muscle). One study did not report the stretching duration (24).

- Stretching frequency (more vs. less than three times per week)

Five studies imposed more than three stretch sessions per week (22, 23, 26, 29, 30), with three showing a benefit of stretching with respect to SRI reduction. Three studies suggested fewer than three stretch sessions per week (24, 27, 28). Of these, none demonstrated significant differences. Lastly, Jamtvedt et al. (25) did not impose any session frequency, which means that participants stretch 1-7 times a week (33.8% 3 times, 18.9% 4 times, 17.8% 2 times and 16.0% 5 times). On this, the article showed a significant benefits of stretching for SRI prevention.

- Stretching timing (before vs. after activities/sports)

In sporting world, stretching is commonly used as a routine for warming up and/or cooling down (14). In our case, four studies established stretching after activity (22, 24, 27, 28) and only one showed a positive result of the intervention. Two studies imposed stretching before activity (23, 30), with no significant results. Two studies examined the effect of stretching when applied before and after activity (25, 29). Both cases showed no effect on total injury rates, but did on the prevalence of acute muscle/ligament injuries. Finally, Liu et al. (26) demonstrated significant positive outcomes when stretching was performed at three distinct times of the day, without relation to PE sessions.

- Type of injury (all types vs. specific injury rates)

Five studies analysed all types of injuries (23, 25, 26, 29, 30) and only one reported a significant positive impact. However, of these six studies, two confirmed the benefit of stretching when focused on muscle/tendon/ligament injuries (25, 29). The other four studies checked specific injuries (2 studies for hamstrings (24, 26), 1 study for Achilles and patellar tendon (27), and 1 study for shoulder (22)). Neither of the hamstring studies showed significant impacts from the stretching programme, whereas the shoulder and patellar tendon studies reported a significant advantage.

Table 1 - Characteristics and Content of Identified Studies

| Authors                       | Design | Number participants | Sex | Sport/ activity | Level        | Intervention Group  | Sessions + Stretch Duration | Stretched Muscles                                | Study period (month) | Quality Score |
|-------------------------------|--------|---------------------|-----|-----------------|--------------|---|-----------------------------|--|----------------------|---------------|
| <i>Shitara et al. (2017)</i>  | RCT    | n = 92              | M   | Baseball        | Club         | Post SS* vs. ST* vs. Post SS + ST vs. No intervention     | 1/d<br>5min                 | Internal rotators shoulders                      | 5                    | 4             |
| <i>Baltich et al. (2016)</i>  | RCT    | n = 129             | Mix | Runner          | Novice       | Pre SS, DS* vs. Functional ST vs. Resistance ST           | 3 to 5/wk<br>20min          | Groin, gluteus, quadriceps, hamstrings, calves   | 6                    | 4             |
| <i>Bello et al. (2011)</i>    | CCT    | n = 14              | Mix | Soccer          | Club         | Post SS, PS vs. Post RS* exercises                        | 3/wk                        | Thigh and leg muscles                            | 4                    | 4             |
| <i>Jamtvedt et al. (2010)</i> | RCT    | n = 2377            | Mix | PE              | Recreative   | Pre & Post SS vs. No stretching                           | 1 to 7/wk<br>At least 14min | 7 lower body muscle groups                       | 3                    | 7             |
| <i>Fredberg et al. (2008)</i> | RCT    | n= 242              | Mix | Soccer          | Professional | Post SS + Eccentric exercises vs. Normal training routine | 3/wk<br>Less than 10min     | Quadriceps and calves                            | 12                   | 4             |
| <i>Liu et al. (2008)</i>      | RCT    | n = 122             | M   | PE              | Recreative   | SS vs. Routine extension movement                         | 3/d<br>1min                 | Calves   | 3                    | 6             |
| <i>Gabbe et al. (2006)</i>    | RCT    | n = 220             | Mix | Soccer          | Club         | Post SS vs. Eccentric exercises                           | 2 to 3/wk<br>15min          | Hip flexors, hamstrings, calves, lumbar rotators | 3                    | 6             |
| <i>Amako et al. (2003)</i>    | RCT    | n = 901             | M   | Military        | --           | Pre & Post SS vs. Unsupervised warm-up                    | 1/d<br>20min                | 4 upper body<br>7 trunk<br>7 lower body          | 3                    | 4             |
| <i>Pope et al. (2000)</i>     | RCT    | n = 1538            | M   | Military        | --           | Warm-up + SS vs. Warm-up only                             | 3,5/w<br>3-4min             | Groin, quadriceps, hamstrings, iliopsoas, calves | 3                    | 7             |

\*SS : static stretching / \*ST : strength training / \*DS : dynamic stretching / \*RS : rhythmic stabilization

Table 3 - Description of Results

| Authors                | Study strengths   | Study weaknesses  | Findings  | Statistical Findings<br>(Intervention vs Control)   |
|------------------------|---|---|---|---|
| <b>Shitara et al.</b>  | Focus on shoulder injury (sport-related) Randomized trial                   | No randomly assign (possible self-selection biases)   | Daily shoulder stretching may reduce incidence of injuries in baseball players  | Shoulder injuries p=0.04  |
| <b>Baltich et al.</b>  | Injury incidence recorded Randomized trial                                  | Poor adherence, dropout rate ~50%   | Injury rate between resistance ST*, functional ST and stretching are similar  | Running injuries incidence rate (26.7 vs 32), CI: 15.2 - 50.5   |
| <b>Bello et al.</b>    | Controlled trial  | Small sample  | No significant difference between RS* and PS*/SS* to prevent injuries in indoor soccer athletes   | Hamstrings/ankles injuries p=0.192  |
| <b>Jamtvedt et al.</b> | Very large sample, Injury incidence recorded Randomized trial               | Data self-reported (internet-based trails) Protocole not standardised (nb stretching session, trainings)                    | Stretching doesn't reduce risk of LL injuries, but reduce risk of injuries to muscles, ligaments and tendons. Stretching reduced risk more in young than older adults   | All injuries : p=0.69<br>Muscles/ligaments/tendon injuries incidence rate (0.66 vs 0.88) p=0.03<br>Correlation age/effect stretching on all injury risk p=0.039 |
| <b>Fredberg et al.</b> | Large sample, focus on tendons (patellar & Achilles) Randomized trial       | Multi component intervention (stretching + eccentric) ; control group : unsupervised warm-up (which can include stretching) | Stretching and eccentric exercises significantly reduce frequency of abnormalities in patellar but not Achilles tendons. It doesn't reduce risk of developing symptoms and can increase injury risk in some cases | Patellar tendons p=0.02 Achilles tendon p=0.75 Both p=0.02 Increased risk of Jumper's knee p=0.04   |
| <b>Liu et al.</b>      | Focus on LL* extremities, Randomized trial                                  |   | Increase calves flexibility reduce incidence of LL overuse injuries   | Lower extremity injuries p < 0.05   |
| <b>Gabbe et al.</b>    | Focus on hamstring injuries, Large sample Randomized trial                  | Poor compliance, drop out (~50%) mainly because of DOMS*  | Eccentric program is not more efficient than stretching for hamstring prevention injury   | Hamstring injuries p=0.098  |
| <b>Amako et al.</b>    | Large sample, Injury incidence and location recorded Randomized trial       | Military recruits easily injured. Control group : unsupervised warm-up (which can include stretching)                       | No significant difference in injury rate. SS can prevent both muscle and low back injuries. Tendency of stress fracture and overuse shin splints (not significant) in stretching group                            | All injuries : p=0.12 Muscle/tendon injuries (2.5% vs 6.9%) p < 0.05 Spinal injuries (1% vs 3.5%) p < 0.05 Incidence LL injury (31% vs 16.1%)                   |
| <b>Pope et al.</b>     | Very large sample, injury incidence and location recorded. Randomized trial | Military recruits easily injured. Protocole : only 20 sec stretch to multiple muscle group                                  | Pre exercise stretching doesn't produce reduction in risk of LL injury  | All injuries : p=0.67 Soft tissue injuries : p=0.17 Bone injuries : p=0.27  |

\*ST : strength training / \*RS : rhythmic stabilization / \*PS : passive stretching / \*SS : static stretching / \*LL : lower limb / \*DOMS : delayed onset muscle soreness

Table 4 - Prevalence of injuries in stretch intervention versus control groups and the associated odds ratio (OR)

|                        |                     | Stretch Intervention            |                           | Control                         |                                 | Odds Ratio       |             |
|------------------------|---------------------|---------------------------------|---------------------------|---------------------------------|---------------------------------|------------------|-------------|
|                        |                     | Events                          | Total                     | Events                          | Total                           | 95% CI / p-value |             |
| <i>Shitara et al.</i>  | 1                   | 8                               | 32                        | 8                               | 14                              | 0.44             | p = 0.04    |
|                        | 2                   | 8                               | 32                        | 16                              | 46                              | 0.72             | p = 0.50    |
| <i>Baltich et al.</i>  | 3                   | 15                              | 43                        | 16                              | 43                              | 0.94             | ?           |
|                        | 4                   | 15                              | 43                        | 21                              | 43                              | 0.71             | ?           |
| <i>Bello et al.</i>    | *(injury incidence) | 9*                              | 7                         | 5*                              | 7                               | 1.8              | p = 0.096   |
| <i>Jamtvedt et al.</i> |                     | 339                             | 1220                      | 348                             | 1157                            | 0.92             | 0.75 - 1.07 |
| <i>Fredberg et al.</i> |                     | 29                              | 86                        | 45                              | 121                             | 0.91             | p = 0.01    |
| <i>Liu et al.</i>      |                     | 9                               | 61                        | 19                              | 61                              | 0.47             | ?           |
| <i>Gabbe et al.</i>    |                     | 8                               | 106                       | 10                              | 114                             | 0.86             | 0.5 - 2.8   |
| <i>Amako et al.</i>    |                     | 58                              | 518                       | 56                              | 383                             | 0.76             | p = 0.12    |
| <i>Pope et al.</i>     |                     | 158                             | 735                       | 175                             | 803                             | 0.98             | 0.77 - 1.18 |
| <b>TOTAL</b>           |                     | <b>654</b>                      | <b>2876</b>               | <b>721</b>                      | <b>2785</b>                     | <b>0,878</b>     |             |
|                        |                     | 1 - Stretch vs. No intervention | 2 - Stretch vs. (SS + ST) | 3 - Stretch vs. (Resistance ST) | 4 - Stretch vs. (Functional ST) |                  |             |

## Discussion

The effectiveness of stretching on injury prevention is unclear based on the results. Nonetheless, this might be dependent upon a variety of parameters. This review finds that three RCTs showed the effectiveness of stretching for the prevention of injuries, whereas five RCTs and one CCT showed no effect. However, a positive effect was found in the majority of RCTs when talking about SRIs. The analysis of five identified confounding factors provided a better understanding of this tendency. On the whole, the type of sports activity factor indicates that stretching was likely to be more beneficial for injury prevention in sports related to acute injuries (sprint component) but not in overuse injuries (endurance activities). The results regarding stretching duration are inconclusive if either a short or long stretching durations decrease the risk of SRI. The number of stretching sessions might be important, with the greater potential to reduce injuries when the stretching protocol is applied more than three times a week. From our research, it is not possible to define if stretching before or after has the best potential impact. However, we believe that stretching before and after activity seems to be the best combination. Finally, all types injuries do not seem to be reduced by stretching while the prevalence of acute muscle injury seems to favourably respond to stretching prevention programmes.

As seen previously from the results of type of activity and types of injury factors, stretching seems to significantly decrease SRIs when it includes a high intensity stretch-shortening cycle component (sprint, explosive-type movement). This fact can be explained by the tendon compliance aspect. Although stretching improves flexibility, increased flexibility does not correlate with a reduction in SRIs (31). Immediately after static stretching, the structure of the tendon changes ; its stiffness decreases and its viscoelastic properties improves (15, 32). These changes lead to first, an increase in its maximal energy-absorbing capacity, and second, a reduction in energy transfer to the contractile muscle tissue, which preserves the muscle structure. As a result, the compliance of the tendon unit increases. Therefore in jumping or sprinting activities, a high compliance should be reachable (14). Tendons need a high tendon compliance to store and release elastic energy that require performance in such activities. Furthermore, it is known that muscle strain injury mainly occurs during eccentric exercise, in the lengthening phase (33). The lack of tendon compliance could explain this outcome: as the stretched tendon is unable to absorb the maximal energy, more energy is transferred to the muscle tissue, which leads its length until its threshold, and its tear.

In low intensity stretch-shortening cycles component, which include endurance sports such as swimming, cycling and running, a different reasoning arises. The compliance of the tendon shows little interest in this case. Indeed, energy absorbing is low in these activities : a stiff tendon would successfully achieve the task. From our research, in the case of endurance sports, stretching does not show a decrease of SRIs ; however, it could result in a decrease in joint stability, an increase in tissue compliance, the overstretching of ligaments, a decrease strength before training and an increase in pain tolerance leading to musculoskeletal/tissue damage (15, 34). Based on this review, we can explain why stretching programmes seem

more efficient for acute SRIs than for overuse injuries and why they show no significant reduction in overall injuries, but do particularly for muscle/ligament injuries.

Although each stretching technique has its own characteristics, no study has demonstrated its specific impacts on injury prevention. The physiological changes in muscle tissue between the stretching techniques is well documented. Studies have compared static, dynamic and PNF stretching (15, 32, 35). For instance, studies have demonstrated that if passive stretching is performed for more than 60 seconds, strength decreases while below 60 seconds, there is no decrease in strength (36, 37) ; that dynamic stretching does not show any negative aspect on performance (38, 39); and that PNF stretching seems to improve performance (40, 41). Depending on the result athletes are looking for (strength, performance or flexibility), they know which stretch they should apply. Nonetheless, no study has compared the SRIs prevention of these techniques. To date, their specific impact on this field is unknown, and this review does not clarify this point either. From our research, the duration of the stretch does not seem to have a significant impact, the frequency of stretching session tends to have a positive impact when applied more than three times a week, and the timing of the stretching session is unclear. These findings must be confirmed by further research.

When comparing stretching with other prevention programmes, no significant benefit was found (23, 24, 28). Yet, several studies recommend a multicomponent programme approach, which consists of combining different prophylactic training interventions, such as stretching with strength, proprioception, balance and/or plyometrics (7, 8, 31, 42). These studies claim that multicomponent exercise programmes can prevent SRIs. This approach has a more positive result than stretching alone. Yet, stretching leads to other results than simply injury prevention. It has been proven that it improves athletic flexibility, influences running economy, enhances athletic performance, improves the joint range of motion and can even enhance well-being (43). Even if the impact on SRIs is not fully convincing, this shows other aspects that are not negligible for athletes.

## **Limitations**

This review raised a potential risk of biases. There is a possibility of performance bias due to the lack of blinding components (assessors, participants and therapists) for most of the articles used ; selection bias due to baseline differences between the study groups ; detection bias because of the different timings of the outcome measurement ; and attrition bias because of the lack of intention-to-treat analysis or the high level of dropout rate (reaching 50% for two RCTs). These potential biases are described in **Table 2** and **Table 3**. Because of all these requirements, it was an arduous task for studies to attain a high quality score based on the PEDro scale. Owing to the different intervention designs between studies, general heterogeneity was an important limitation for this review.

Yet, this review has its strengths. All studies were clinical trials, with eight RCTs and one CCT. All but one of these randomly allocated participants. For the non-randomly assigned group, the authors acknowledged the risk of bias and defended themselves by claiming a lack of ethics in the conduct of randomly allocated participants, because of the higher risk of



potential in the control group (22). Some focused on only one group of muscle injuries (shoulders, Achilles and patellar tendons, calves), which allowed a precise analysis of stretch incidence in a specific body area, while others had a large sample (up to 2377).

## Conclusion

Based on nine moderate-to-high quality clinical trials, this systematic review seems to provide reliable evidence that stretching programmes do not reduce overall injury rates. Secondary findings indicate, however, that stretching may have a positive effect on preventing musculotendinous injuries. This statement is valid when sports typically cause acute injuries (sprint components) but not overuse injuries (endurance activities). Hence, when talking about SRIs, specifically acute injuries, stretching is an effective tool for SRI prevention. Further studies, focus on sport-related acute injuries, should be performed in sprint, explosive-type movement to confirm these findings.

## Relevance

The dissemination of this scientific evidence to the professionals of the medico-sports staff (e.g. physical trainers, trainers, physiotherapists, doctors ...) would modify certain potentially deleterious empirical practices with the aim of preserving health. Of course, the conclusion is hard to apply as intensity differs from one player to another, even in the same sports. However, we hope that sports staff would have a better understanding of the effect of stretching applied in training.

It must be acknowledged that the aetiology of injury is multifactorial and that if injury prevention is the main goal defined by coaches, they should apply a multicomponent prevention approach. Besides this approach, additional techniques, such as active recovery, massage, compression, immersion, contrast water therapy and cryotherapy induce to reduce muscle damage, DOMS, fatigue and inflammation (44). Many tools are available to reduce the risk of SRIs, and it is the coaches' role to investigate the prevention approaches/interventions that best fit their training methods.

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