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# Stretching Before and After Exercise: Effect on Muscle Soreness and Injury Risk


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***Reference:*** Herbert RD, Gabriel M. Effects of stretching before and after exercise on muscle soreness and risk of injury: systematic review. *BMJ.* 2002;325:468.

***Clinical Question:*** Among physically active individuals, does stretching before and after exercise affect muscle soreness and risk of injury?

***Data Sources:*** Studies were identified by searching MEDLINE (1966–February 2000), EMBASE (1988–February 2000), CINAHL (1982–1999), SPORT Discus (1949–1999), and PEDro (to February 2000). I searched the reference lists of identified studies manually until no further studies were identified. The search terms *stretch, exercise, warm-up,* and *cool down* were used in all databases except MEDLINE. In MEDLINE, an optimized OVID search strategy was used. This strategy included the terms searched in the other databases as well as terms such as *flexibility, athletic injuries, sports, soreness,* and *muscle*.

***Study Selection:*** The search was limited to English-language articles obtained from the electronic searches and the subsequent manual searches. This review included randomized or quasirandomized investigations that studied the effects of any stretching technique, before or after exercise, on delayed-onset muscle soreness, risk of injury, or athletic performance. Studies were included only if stretching occurred immediately before or after exercising.

***Data Extraction:*** Data extraction and assessment of study quality were well described. The principal outcome measures were measurements of muscle soreness and indices of injury risk. Results from the soreness studies were pooled by converting the numeric scores to percentages of the maximum possible score. These data were then reported as millimeters on a 100-mm visual analogue scale. Results of comparable studies were pooled using a fixed-effects model meta-analysis. Survival analysis using a Cox regression model was calculated on the time-to-event (injury) data.

***Main Results:*** The total number of articles identified using the search criteria was not provided; however, 5 studies on stretching and muscle soreness met inclusion and exclusion criteria. All of the studies meeting the criteria employed static stretching. One group reported the findings from 2 experiments, resulting in 6 studies meeting the inclusion and exclusion criteria. For the risk of injury, 2 studies, both investigating lower extremity injury risk in army recruits undergoing 12 weeks of basic training, met inclusion and exclusion criteria. On the basis of the PEDro scale, the methodologic quality of the studies included in the review was moderate (range, 2–7 of 10), with a mean of 4.1. For the studies on muscle soreness, 3 groups evaluated postexercise stretching, whereas 2 evaluated preexercise stretching. The participant characteristics from the 5 studies were noted to be reasonably homogeneous. Subjects in all studies were healthy young adults between the ages of 18 and 40 years (inclusive). For all studies but one, total stretching time per session ranged from 300 to 600 seconds. The exception was one study in which total stretching time was 80 seconds. Data from 77 subjects were pooled for the meta-analysis of muscle soreness outcomes at 24, 48, and 72 hours after exercising. At 24 hours postexercise, the pooled mean effect of stretching after exercise was −0.9 mm (on a 100-mm scale; negative values favor stretching), with a 95% confidence interval (CI) of −4.4 to 2.6 mm. At 48 hours, the pooled mean effect was 0.3 mm (95% CI = −4.0 to 4.5 mm), whereas at 72 hours, the pooled mean effect was −1.6 mm (95% CI = −5.9 to 2.6 mm). In each of these analyses, the results were not statistically significant in favor of either stretching or not stretching. For the studies on risk of lower extremity injury, the authors provided time-to-event (injury) data from 2630 subjects (65 military trainee platoons). These data were then combined and resulted in the allocation of 1284 subjects to stretching groups and 1346 subjects to control groups. The survival analysis identified a pooled estimate of the all-injuries hazard ratio of 0.95 (ie, a 5% decrease in injury risk; 95% CI = 0.78 to 1.16), which was not statistically significant.

***Conclusions:*** The data on stretching and muscle soreness indicate that, on average, individuals will observe a reduction in soreness of less than 2 mm on a 100-mm scale during the 72 hours after exercise. With respect to risk of injury, the combined risk reduction of 5% indicates that the stretching protocols used in these studies do not meaningfully reduce lower extremity injury risk of army recruits undergoing military training.


## COMMENTARY

Stretching before or after physical activity can be observed daily in the clinical setting and in the community, as clinicians and patients use stretching to prevent injury, decrease soreness, and improve performance. These concepts are also often cited in textbooks as being among the important reasons to include stretching in an injury-prevention program.[1,2] Also, preactivity or postactivity stretching to prevent or alleviate postexercise muscle soreness, if effective, could have a positive effect on subsequent physical activity.

That is, if stretching effectively reduces soreness, then future performance may be relatively unaffected.[3] In contrast, the results of this systematic review by Herbert and Gabriel do not support the role of stretching, as performed in the included studies, in decreasing muscle soreness after exercise.

The preexercise stretching protocols used in the included studies on muscle soreness typically consisted of 2 to 10 repetitions held for 20 to 120 seconds for up to 4 days after exercise. The postexercise protocols used typically consisted of 4 to 10 repetitions held for 30 to 120 seconds. On the basis of their meta-analysis of the muscle soreness studies, the authors observed, on average, a 2% reduction in soreness over the first 72 hours after exercise. This reduction is likely to be of little or no practical significance to most patients treated by athletic trainers or other health care professionals. In addition, these observations are consistent with the results obtained with other interventions aimed at decreasing postexercise muscle soreness.[3]

With respect to stretching and lower extremity injury risk reduction in army recruits, the stretching protocols consisted of either two 20-second stretches of the soleus and gastrocnemius muscles on each side or one 20-second stretch of the gastrocnemius, soleus, hamstring, quadriceps, hip adductor, and hip flexor muscle groups on each side. In their meta-analysis, Herbert and Gabriel indicated that the stretching protocols used in the included studies demonstrated an all-injury risk reduction of 5%. The stretching program was conducted for 40 exercise sessions during the 12-week training period. Although this stretching protocol has some similarities to the protocol advocated by the American College of Sports Medicine to improve flexibility, it does not replicate the recommended total volume of stretching.[4] In addition, the authors of one of the included studies suggested that the stretches performed by their subjects may not have been sustained long enough to effect changes in the musculotendinous unit to reduce injury risk.[5] Putting the results of these studies in practical terms, however, indicates that about 141 people would need to stretch for 12 weeks to prevent 1 injury.[6] Applying these findings to the broader athlete population, who likely have a lower injury risk than army recruits, the authors stated that the risk reduction would likely be smaller than 5%. These studies used the selected protocols described above; the potential benefits of other stretching protocols are unknown at this time.

This systematic review by Herbert and Gabriel has several limitations. An important limitation is the inclusion of articles only written in English, which may result in bias in the conclusions.[5] The authors acknowledged this potential bias in their discussion and further stated that a search for non–English language articles did not identify any articles meeting the inclusion criteria. Another limiting factor is their inclusion of both randomized and quasirandomized studies in the systematic review. By doing this, the authors may have confounded their ability to reduce bias and random error among the included studies.[5] This potential confounding could be detrimental to the strength of the evidence reported in the review. However, this observation is likely most important for the muscle-soreness component of the review, as the injury-risk component included only randomized studies.[5]

In view of the limitations of the review, the evidence presented here indicates that neither pre-exercise nor postexercise stretching positively affects soreness. This observation is consistent with the extensive body of literature on the treatment of postexercise muscle soreness, indicating that no nonpharmacologic intervention has a significant effect on soreness.[3] However, the authors stated there is a need to conduct randomized studies of sound methodologic quality on stretching and its effect on postexercise muscle soreness.

With respect to injury risk reduction, the authors have provided strong evidence from randomized trials that pre-exercise stretching of the major lower extremity musculature using a specific stretching protocol does not result in a meaningful reduction of lower extremity injury risk. However, because these investigators only studied army recruits, the authors stated it would be interesting to assess the effect of more prolonged stretching performed by recreational athletes over an extended time (ie, months or years) on injury risk reduction.

Although investigating stretching in athletes over a prolonged period would seem to be the next logical step in the study of stretching and injury risk reduction, some insights from Shrier suggest otherwise.[7] That is, during his review of the basic science literature, he noted 5 theoretic arguments against pre-exercise stretching for injury prevention. One argument deals with the concept of compliance in muscles (ie, the length change of a muscle when force is applied). As seen in the basic science literature, increased muscle compliance is associated with a decreased ability to absorb energy in a muscle at rest, whereas a contracting muscle is less compliant but can absorb more force. Therefore, greater compliance, which can be achieved through stretching, is not necessarily related to the tissue's resistance to injury.[7] A second concept presented is related to the observation that sarcomere length in an active muscle is heterogeneous. This is significant during muscle activity because when some sarcomeres are stretched to the point that the actin and myosin filaments do not overlap, the force being absorbed is transmitted to the muscle fiber cytoskeleton, resulting in fiber damage. In addition, the basic science literature indicates these events can happen when the joint is within its normal range of motion. Therefore, muscle compliance may be irrelevant to injury, whereas loss of energy-absorbing capacity of overstretched sarcomeres is of greater importance.

Another issue is the observation that muscle tissue compliance at rest and during activity is unrelated. This observation, in conjunction with the belief that injuries occur when a muscle is active, indicates that stretching, which increases compliance at rest, does not support the concept of decreased injury risk when the muscle is active. The basic science literature has also shown that stretching muscle as little as 20% of its resting length, which can occur during correct stretching techniques, can produce damage in isolated preparations.[7] These findings indicate that it may be difficult to define the correct stretching techniques to reduce injury risk. The final argument is based on the observation that increased range of motion occurring with stretching may be in part a result of an increase in stretch tolerance. That is, stretching does not improve tissue compliance; rather, the stretching exercises increase stretch tolerance (ie, reduce pain) during the stretching procedure.

In summary, the results of this review do not support the role of pre-exercise or postexercise stretching as an intervention addressing postexercise muscle soreness. In addition, the evidence presented in this review does not support the role of pre-exercise stretching in the reduction of lower extremity injury risk. However, it should be understood that we need further studies of stronger methodologic quality and studies that focus on other regions of the body as well as on the lower extremity. We also need further study of the longitudinal application of stretching and injury risk reduction. Investigators should take into account the insights obtained from the basic science literature and make efforts to apply this information in clinical studies.

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