

Can Stretching Prior to Exercise and Sports Improve Performance and Prevent Injury?

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Learning Objective

To learn about the research on stretching as it relates to enhanced performance and injury prevention so that fitness, exercise, and sports performance professionals can make better, more educated, decisions about stretching programs for their clients.

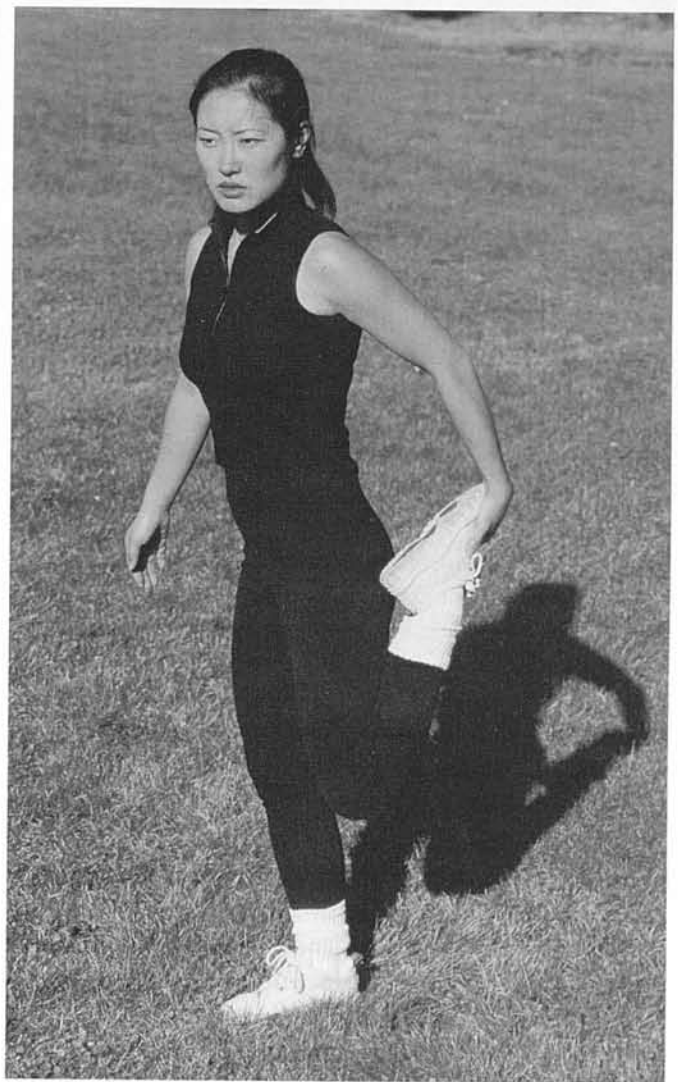
In the field of exercise and sports training, stretching is one of the most misunderstood components of fitness. This lack of knowledge about stretching is because little definitive scientific research has been published, and the exercise professional has been left to interpret what has been published. As a result, a variety of perceived notions about stretching have become popular.

Research on stretching prior to exercise for injury prevention and improved performance needs to be reviewed. Shrier and Gossal (1), in a review of stretching research, indicated that there is limited scientific evidence about the benefits of stretching, and recent research is challenging some long-held beliefs about the use of stretching prior to exercise. Taylor and his associates (2) agreed that stretching is popular in sports, dancing, and fitness; there is, however, a lack of good scientific information to justify its extensive use for injury prevention and performance enhancement.

The Physiology of Stretching

When we stretch, the muscle and tendons are stretched. Taylor et al. (2) indicated that the viscoelastic properties of the muscle-tendon unit are responsible for the increased length of the muscle.

Within the muscle and tendon, muscle spindles and Golgi tendon organs protect the muscle from being overstretched. Both are highly sensitive receptors that provide sensory information about changes in length and tension (3). The muscle spindle is functionally significant in exercise and sport because it has the ability



to detect, respond to, and make changes in the length of skeletal muscles.

The primary function of the muscle spindle is to respond to stretching and, through a reflex action, evoke a muscle action to reduce the stretch that protects the muscle and

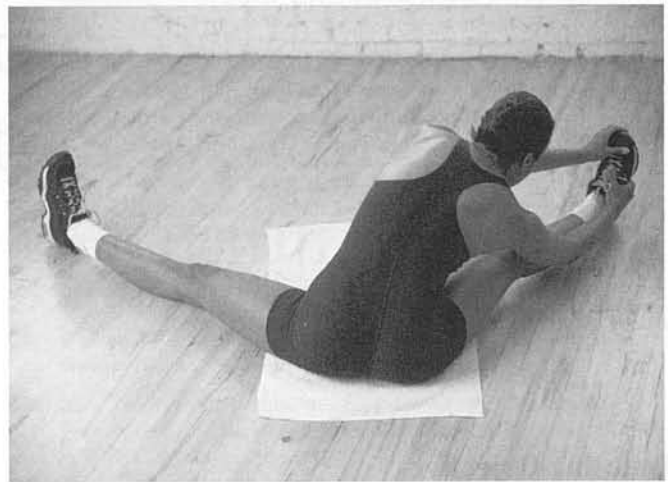
tendon from injury (3). The muscle spindle is aligned parallel to the regular muscle fibers (extrafusal fibers), and when skeletal muscle stretches, the spindle stretches. The spindle contains two specialized fibers called intrafusal fibers. At the ends of each intrafusal fiber are actin and myosin that make it possible for these fibers to contract. Generally speaking, the muscle spindle monitors the amount of stretch on a muscle. If the stretch is perceived as dangerous, the intrafusal fibers contract causing the extrafusal fibers to contract, thus stopping the stretch and preventing injury (3).

The Golgi tendon organs are located in the tendons near the junction of the muscle. The primary function of the Golgi tendon organs is to monitor tension on the muscle and tendon. When they sense too much tension on the muscle, they cause a reflex inhibition of the muscle, causing the muscle to relax thus protecting the muscle and tendon from injury caused by excessive load (3).

Effects of Stretching on the Muscle

Behm et al. (4) studied the factors causing the loss of force after prolonged static, passive stretching. Sixteen subjects performed five sets of three lower limb stretches, holding each stretch for 45 seconds followed by a 15-second relaxation period. The total stretch time was 20 minutes. After the stretching protocol, the following tests were conducted: 1) isometric maximal voluntary contraction force (MVC), 2) surface integrated electromyographic (iEMG) activity of the quadriceps and hamstrings, 3) twitch and titanic force contractile properties, and 4) quadriceps inactivation as measured by interpolated twitch technique (ITT). The authors indicated that the study's most important contribution is the idea that a protocol of prolonged, static, passive stretching can inhibit MVC, which may be partially caused by decreases in muscle activation of the knee extensors.

Kokkonen et al. (5) used 26 subjects to investigate strength endurance performance after acute static stretching. The subjects first performed a sit-and-reach test followed by a maximal hamstring strength-endurance test. Forty-eight hours later, the subjects participated in a 20 minute static stretching session for the hamstrings and gastrocnemius, followed by a sit-and-reach test and 10 minutes after the static stretching, a maximal hamstring strength-endurance test. The authors reported a significant decrease in the number of repetitions in the maximal hamstring strength-endurance test after the 20 minutes of static stretching. The decrease in the number of repetitions could have been caused by metabolic alterations or inhibition in the nervous system. The authors speculated that it could also be because



of a decrease in maximal strength after heavy static stretching and recommend that static stretching lasting 10 minutes should be avoided prior to a maximum strength-endurance effort.

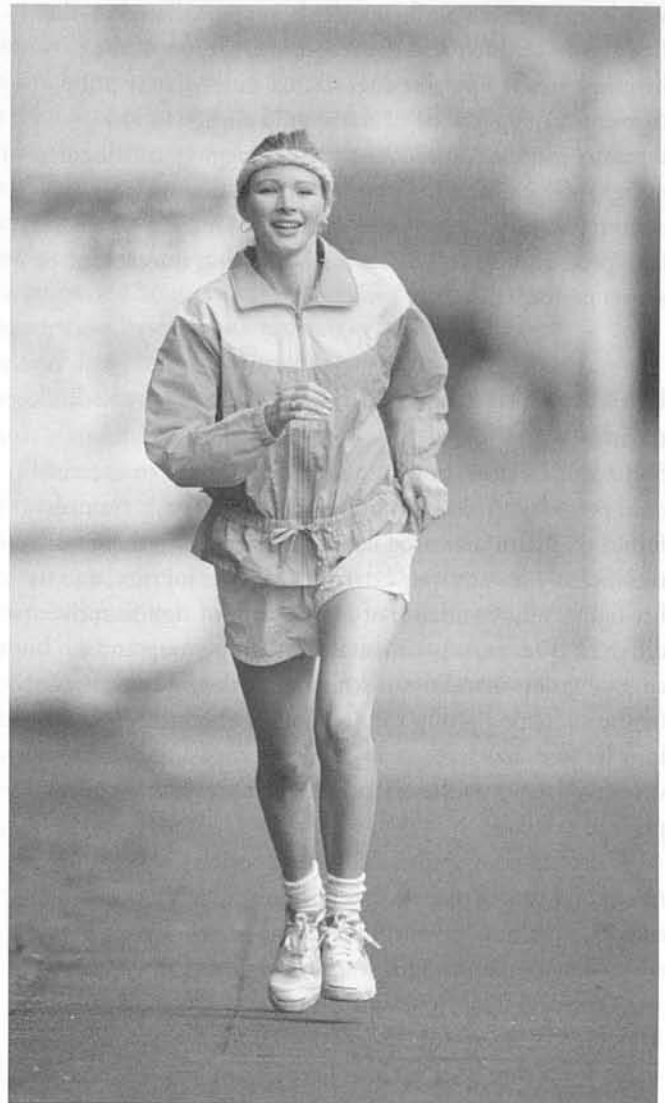
An investigation conducted by Kokkonen et al. (6) using 30 male and female subjects looked at the effect of a 20 minute acute passive stretching protocol on one repetition maximum of the knee extensors and flexors. The control group performed no stretching while the experimental group engaged in 20 minutes of passive static stretching of the hip, thigh, and calf. A maximum of one repetition of the knee flexors and extensors was performed before and after the treatments. After the stretch protocol, the subjects experienced a significant decrease in their one repetition maximum performance of 7.3% for knee flexion and 8.1% for knee extension. The authors suggested that the stretching may influence maximal strength through a reduction of passive or active stiffness of the musculotendinous unit. The authors also suggested that intense static stretching of the prime movers prior to a particular skill in which the prime movers would be used should not be undertaken in events that require a maximal strength output.

Rosenbaum and Henning (7) investigated the acute effects of warm-up and stretching on electromyographic (EMG) and force output of mechanically elicited triceps surae reflexes on 50 male subjects. The subjects performed eight reflex experiments under each of three successive conditions in one session: 1) no prior exercise, 2) after three minutes of static stretching of the passive triceps surae, and 3) after a 10-minute warm-up run on a treadmill. The authors concluded that the stretching treatment impaired active force production, which may be because of mechanical changes such as increased tendon slack. There was a reduced passive force peak indicating an improved

stretch absorbing capacity and could be viewed as being beneficial for injury prevention. The main result of the running treatment was improved force development after tendon tap. EMG parameters reduced peak-to-peak amplitudes after each treatment, which led to changes in force-to-EMG ratios. The practical application of the results of this study suggest that it is not advisable to use only static stretching prior to exercise. If stretching is followed by a general warm-up, such as a 10 minute run, this can lead to improved force development.

Taylor and associates (2) used the muscle tendon units of the extensor digitorum longus and tibialis anterior from rabbits to evaluate the use of widely used stretching methods on biomechanical stretching properties. The investigators used three parts to their study: 1) repeated stretching to 10% beyond resting length of the muscle, 2) repeated stretching of the muscle to a set tension (starting at 1.96 N and progressing at a rate of 2 cm/min to 78.4 N), and 3) stretching of the muscle at varying rates and comparing innervated and denervated muscle. The results of the study indicated the following: Part 1) 16.6% decrease in peak tension from the 1st to the 10th stretch cycle, Part 2) a 3.46% increase in length of the extensor digitorum longus, and Part 3) all muscles tested exhibited increased peak tensile forces and greater absorbed energies when stretched at faster rates. The authors offered the following suggestions to explain the results: the decline in peak tension occurs because the viscoelastic property of stress relaxation leads to an internal change in structure, and the increased length of the muscles following stretching may indicate that the muscles were at a disadvantageous point on the force:length curve when they began transmitting force from the muscle to the tendon to the bone to create movement.

Fowles et al. (8) used 10 men and women to assess strength performance after an acute bout of maximally tolerable passive stretch on the plantar flexors. The subjects performed 13 stretches, holding each stretch for 135 seconds during a period of 33 minutes. A control group performed no stretching. Maximal voluntary isometric contraction with twitch interpolation, electromyography, and twitch characteristics were tested prestretch, immediately after, and 5, 15, 30, 45, and 60 minutes poststretch. Post test results showed maximal voluntary contraction decreased at post (28%), 5 min (21%), 15 min (13%), 30 min (12%), 45 min (10%) and 60 min (9%). Motor unit activation and electromyogram were significantly depressed immediately after stretching but recovered 15 minutes poststretch. The authors' results indicated that an intense prolonged stretch of the plantar flexors reduces maximum voluntary force for up to one hour



after stretching. Decreased maximum voluntary force may be partly caused by reduced activation and reduced muscle force generating capacity. Complete recovery of the force generating capacity is prolonged which is similar to the recovery of muscle stiffness. Stiffness recovery may represent mechanical "recoil" from the stretching.

Based on this research, it appears that the muscle, the tendon, and/or the muscle tendon unit becomes weaker and is less able to produce high intensity force or has a period of time during which the muscle stays stretched. There appears to be a "lag" period after stretching, during which, if the muscle is contracted, it must "take up the slack" before the peak tension is reached.

With these findings in mind, it appears that stretching immediately prior to exercise or sports performance, without appropriate time for the muscle to take up the "slack" caused by stretching, may cause a strength deficit,



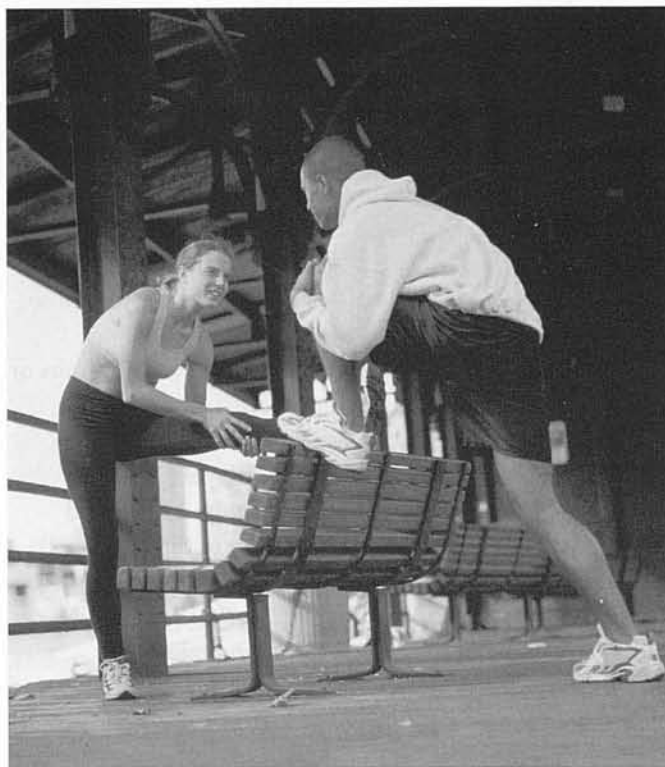
which may cause a performance decrement. Based on the findings of research and the recommendations of the investigators, if a person does stretch immediately prior to exercise or sports, he or she should engage in low intensity muscle contractions such as jogging, calisthenics, or light weight lifting. These low intensity muscle contractions will function to tighten the muscle which may help produce a stronger contraction during the exercise or sports performance.

Does Stretching Prior to Exercise Reduce the Risk of Injury?

Some studies have shown that stretching prior to exercise does prevent injuries. Studies with infantry basic trainees found that with increased hamstring stretching there were significantly fewer lower extremity overuse injuries, and in fire fighters the incidence of injury was not significantly different from an experimental stretching group and a control group that did not stretch, but the injuries sustained by the stretching group resulted in less absenteeism and the injuries were less severe. However, these two studies are not very convincing evidence as to the benefits of stretching prior to exercise.

There are many more studies and reviews of literature, recent and not so recent, that indicate stretching prior to exercise does not prevent injury. One study investigated the effects of stretching and not stretching on 1,538 Australian army recruits. The stretching group performed a static stretching protocol for the lower limbs during pre-exercise warm-ups, whereas the control group did not stretch. Their findings showed no reduction in the risk of exercise-related injury between the stretching and control groups. They did report however, that the level of fitness may be an important, modifiable risk factor.

Shrier (9) conducted a review of literature on research relating to stretching and injury. Of the 138 articles retrieved from the search, only 12 used a control group to analyze whether stretching before exercise prevents injury. Of those articles, four found that stretching prior to exercise was beneficial, three studies suggested stretching was actually detrimental, and five suggested there was no difference in injury between subjects who stretched and those who did not stretch. Therefore, in Shrier's review of literature, he reported that 8 of 12 studies suggested that stretching before exercise, to prevent injury, either increased the risk of injury or made no difference in injury rate. It was concluded that the basic scientific literature supports the epidemiologic evidence that stretching before exercise does not reduce the risk of injury.



Van Mechelen et al. (10) studied the effect of a health education intervention, and prerun and postrun exercises, on running injuries. The intervention consisted of health information on, and participation in, a six minute warm-up run, three minutes of what the authors called loosening exercises, and three sets of 10 seconds of static stretching exercises for the iliopsoas, quadriceps, hamstrings, soleus, and gastrocnemius muscles prior to each run. A cool-down intervention, which was the inverse of the warm-up, was performed after each run. The study consisted of 421 male recreational runners who were matched for age, weekly running mileage, and knowledge of preventing injuries. The subjects were randomly selected into intervention and control groups. The subjects were asked to continue to run their normal weekly mileage, which ranged from 6.21 to 19.88 miles or more. The intervention group performed the warm-up, loosening, and stretching exercises before and after each run. At the end of the 16 week study, there were 23 injuries in the control group and 26 injuries in the intervention group. The authors concluded that the health education and participation in a prerun warm-up, a postrun cool-down, and static stretching were not effective in reducing the number of running injuries.

Macera et al. (11) conducted a prospective study of 583 habitual runners to investigate the relationship of suspected risk factors to the occurrence of running-related injuries of the lower-extremities. The authors found that statistically

significant risk factors for men included weekly distance, previous injury, and running inexperience. For women, the only statistically significant risk factor was running on concrete. Conversely, the authors found that body mass index, running hills, running in the dark, running in the morning, and not stretching before running were not risk factors for running-related injuries of the lower-extremities.

In a review by Gliem and McHugh (12), the authors found no clear relationship between flexibility and injury that is applicable to all sports and levels of play. The authors suggested that flexibility may be important in some sports that rely on extremes of motion for performance, but that decreased flexibility may increase economy of movement in sports which use the mid portion of range of motion.

In Shrier's (13) editorial, he used the basic scientific evidence to put the clinical evidence into perspective and offered four reasons why stretching prior to exercise does not reduce injuries. He indicated that there is a belief that a muscle that is more flexible is less likely to be injured. However, he indicated that there is no basic scientific research showing that increased flexibility is associated with a greater ability to absorb energy. The energy that is absorbed before the muscle fails is considered one of the most important factors in injury. His second reason was that most injuries occur during eccentric contractions. An injury during an eccentric contraction can cause damage within a normal range of motion. If an injury occurs within a normal range of motion, increased flexibility would not prevent the injury. His third reason suggested that mild stretching can cause damage at the cytoskeletal level of the muscle, and finally, he suggested that static stretching has an analgesic effect on the muscle, which increases tolerance for pain while stretching. His conclusion was that it does not seem prudent to increase tolerance to pain, cause cytoskeletal damage, and then exercise a damaged and anesthetized muscle.

CONCLUSION

Stretching is a misunderstood component of fitness and sports training. However, new research is clarifying some misconceptions about the effects of stretching. Exercise professionals will be challenged to understand the research and how to apply it in their exercise prescriptions for clients.

Stretching causes the muscle and tendon to lengthen. It has been suggested that the viscoelastic properties of the muscle-tendon unit are responsible for the increased length of the muscle. The muscle spindles and Golgi tendon organs play a role in stretching by monitoring muscle length and tension and causing a reflex inhibition of the muscle.

The research illustrates the effect of many different stretching protocols on the muscle. The research has shown an inhibition of maximal voluntary contraction, a decrease in the number of repetitions in a maximal hamstring strength-endurance test, a decrease in one repetition maximum performance, impaired active force production, a decrease in peak tension, a disadvantageous point on the force:length curve, and a reduced maximum voluntary force for up to one hour after stretching. Reasons for these changes can be mechanical changes such as increased tendon slack, internal change in structure, mechanical "recoil" from the stretching, and a "lag" period where the muscle and tendon stay stretched for perhaps 15 minutes.

Few studies show decreased injury after stretching. Most of the literature is challenging some long held beliefs about the effect of stretching prior to exercise or sports. Army recruits and runners got injured whether they stretched and warmed up or not. Not stretching before running was found not to be a risk factor for injury. It has also been speculated that increased flexibility does not enhance energy absorption, injuries can occur within a normal range of motion, stretching can cause damage at the cytoskeletal level, and stretching may have an analgesic effect on the muscle.



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References

1. Shrier, I., and K. Gossal. Myths and truths of stretching: individualized recommendations for healthy muscles. *Physician and Sportsmedicine* 28: 57-63, 2000.
2. Taylor, D.C., J.D. Dalton, A.V. Seaber, and W.E. Garrett. Viscoelastic properties of muscle-tendon units. *American Journal of Sports Medicine* 18:300-309, 1990.
3. McArdle, W.D., F.I. Katch, and V.I. Katch. *Exercise Physiology: Energy, Nutrition and Human Performance*. Baltimore: Williams & Wilkins, 1996.
4. Behm, D.G., D.C. Button, and J.C. Butt. Factors affecting force loss



with prolonged stretching. *Canadian Journal of Applied Physiology* 26: 262–272, 2001.

5. Kokkonen, J., A.G. Nelson, and D.A. Arnall. Acute stretching inhibits strength endurance performance. *Medicine and Science in Sports and Exercise* 33:11A, 2001.
6. Kokkonen, J., A.G. Nelson, and C. Andrew. Acute muscle stretching inhibits maximal strength performance. *Research Quarterly for Exercise and Sport* 69:411–415, 1998.
7. Rosenbaum, D. and E.M. Henning. The influence of stretching and warm-up exercises on Achilles tendon reflex activity. *Journal of Sports Sciences* 13:481–490, 1995.
8. Fowles, J.R., D.G. Sale, and J.D. MacDougall. Reduced strength after passive stretch of the human plantar flexors. *Journal of Applied Physiology* 89:1179–1188, 2000.
9. Shrier, I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clinical Journal of Sports Medicine* 9:221–227, 1999.
10. Van Mechelen, W., H. Hlobil, H.C.G. Kemper, W.J. Voorn, and H.R. de Jongh. Prevention of running injuries by warm-up, cool-down, and stretching exercises. *American Journal of Sports Medicine* 21:711–719, 1993.
11. Macera, C.A., R.R. Pate, K.E. Powell, K.L. Jackson, J.S. Kendrick, and T.E. Craven. Predicting lower-extremity injuries among habitual runners. *Archives of Internal Medicine* 149:2565–2568, 1989.
12. Gleim, G.W. and M.P. McHugh. Flexibility and its effects on sports injury and performance. *Sports Medicine* 24:289–299, 1997.
13. Shrier, I. Stretching before exercise: an evidence based approach. *British Journal of Sports Medicine* 34:324–325, 2000.

Condensed Version and Bottom Line

Previously it was thought that stretching prior to exercise or sports would decrease the risk of injury. This thought process was based on perceived notions about stretching. Research is now clarifying what happens to the muscle and tendon after static and repeated stretching. There appears to be a weakening of the muscle after static stretching. This muscle weakness can last upwards of fifteen minutes. It has been shown that jogging after stretching, or some kind of muscle contraction, will cause the muscle to reverse the stretch-induced weakness. It is thought that the weakness is caused by some kind of muscle or tendon slack caused by static stretching. It is being proposed that if the muscle is weakened after stretching it is not prudent to exercise immediately after stretching.

Many studies are showing that stretching before exercise, primarily running, does not decrease lower limb injuries. In many of the studies, it did not seem to matter if a subject stretched or not. Subjects who stretched got injured and subjects who did not stretch got injured. In some cases, however, stretching was found to almost enhance the risk of injury.

The recommendations that can be gleaned from the research literature are that one should probably not stretch immediately prior to exercise or sports performance. Instead, a warm-up using the movement patterns of the exercise or sport which will provide a person with injury protection and enhanced performance is recommended. If a person wants to stretch prior to exercise or sports, a warm-up should always follow the stretching.