

## The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature.

### CLINICAL SCIENCES

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#### **Abstract:**

THACKER, S. B., J. GILCHRIST, D. F. STROUP, and C. D. KIMSEY, JR. The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature. Med. Sci. Sports Exerc., Vol. 36, No. 3, pp. 371-378, 2004.

**Purpose:** We conducted a systematic review to assess the evidence for the effectiveness of stretching as a tool to prevent injuries in sports and to make recommendations for research and prevention.

**Methods:** Without language limitations, we searched electronic data bases, including MEDLINE (1966-2002), Current Contents (1997-2002), Biomedical Collection (1993-1999), the Cochrane Library, and SPORTDiscus, and then identified citations from papers retrieved and contacted experts in the field. Meta-analysis was limited to randomized trials or cohort studies for interventions that included stretching. Studies were excluded that lacked controls, in which stretching could not be assessed independently, or where studies did not include subjects in sporting or fitness activities. All articles were screened initially by one author. Six of 361 identified articles compared stretching with other methods to prevent injury. Data were abstracted by one author and then reviewed independently by three others. Data quality was assessed independently by three authors using a previously standardized instrument, and reviewers met to reconcile substantive differences in interpretation. We calculated weighted pooled odds ratios based on an intention-to-treat analysis as well as subgroup analyses by quality score and study design.

**Results:** Stretching was not significantly associated with a reduction in total injuries (OR = 0.93, CI 0.78-1.11) and similar findings were seen in the subgroup analyses.

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#### [More on stretching not preventing injuries](#)

April 27th, 2004

#### [Hold That Stretch: Warm-Up Is Challenged](#)

Now a major study is stirring renewed discussion about when stretching is and is not beneficial.

The study, a review of six decades of research by the Centers for Disease Control and Prevention, found that stretching does little to prevent injury during exercise when done outside of a warm-up. In some cases, the increased flexibility that stretching promotes may actually impede performance.

The researchers analyzed 361 scientific articles on stretching published since 1946. The findings, in the March issue of Medicine and Science in Sports and Exercise, suggest that athletes who devote pre-exercise time to stretching may be better served with a warm-up that prepares the body for activity and regular exercises that build strength and balance.

“The idea of loosening your joints up and muscle stretching makes sense, but the problem is that it really hasn’t been shown to prevent injury,” said Dr. Stephen B. Thacker, director of the epidemiology program office at the C.D.C. and an author of the study. “If you put on your sweats and simply start stretching, your muscles are not necessarily warmed up.”

Warming up, which typically means raising the body temperature enough to send the blood flowing through the muscles, requires more intense activity than stretching.

“For your muscles to function at optimal capability, they should not be too loose nor too tight,” said Dr. Lisa Bartoli, an attending physician in physical medicine and rehabilitation at the Beth Israel Medical Center in Manhattan. She likened warming up the body for exercise to taking modeling clay from a refrigerator. “You warm it up and work it a little bit,” she said. “And then you can stretch it.”

**Like many sports physicians, Dr. Bartoli tells her patients that rather than stretching before physical activity, they should do the sporting activity at 50 percent of the target intensity.**

The argument against stretching does make some sense. You need not take a joint to an angle that you will not be using. Too much laxity may make injury more likely (by preventing resistance to injury).

I like the recommendation of warming up. I notice in golf that a slow warm up leads to better golf swings on the course. I notice that prior to my weight lifting sessions, a moderate aerobic activity of 10-15 minutes helps me get ready for action.

Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sport Med.* 1999;9:221-227.

Does Stretching Improve Performance?: A Systematic and Critical Review of the Literature

*Clinical Journal of Sport Medicine: Volume 14(5) September 2004 pp 267-273.* Shrier, Ian MD, PhD  
Main Results: Of the 23 articles examining the effects of an acute bout of stretching, 22 articles suggested that there was no benefit for the outcomes isometric force, isokinetic torque, or jumping height.

McNeal JR, Sands WA. Static stretching reduces power production in gymnasts. *Technique.* 2001;Nov/Dec:5-6.

McNeal JR, Sands WA. Acute static stretching reduces lower extremity power in trained children. *Ped Exer Sci.* 2003;15:139-145.

Fowles JR, Sale DG, MacDougall JD. Reduced strength after passive stretch of the human plantarflexors. *J Appl Physiol.* 2000;89:1179-1188.

Church JB, Wiggins MS, Moode FM, et al. Effect of warm-up and flexibility treatments on vertical jump performance. *J Strength Cond Res.* 2001;15:332-336.

Nelson AG, Kokkonen J. Acute ballistic muscle stretching inhibits maximal strength performance. *Res Q Exerc Sport.* 2001;72:415-419.

Kokkonen J, Nelson AG, Cornwell A. Acute muscle stretching inhibits maximal strength performance. *Res Q Exerc Sport.* 1998;69:411-415.

Cornwell A, Nelson AG, Heise GD, et al. Acute effects of passive muscle stretching on vertical jump performance. *J Hum Movement Stud.* 2001;40:307-324.

Young W, Elliott S. Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jumping performance. *Res Q Exerc Sport.* 2001;72:273-279.

Young WB, Behm DG. Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *J Sports Med Phys Fitness.* 2003;43:21-27.

Avela J, Kyrolainen H, Komi PV. Altered reflex sensitivity after repeated and prolonged passive muscle stretching. *J Appl Physiol.* 1999;86:1283-1291.

Cramer JT, Housh TJ, Johnson GO, et al. The acute effects of static stretching on peak torque in women. *J Strength Cond Res.* 2004;18:236-241.

## Stretching.....out?

*Some experts contend that static stretching before exercise can prevent injury. Others claim that in fact it can be harmful. And the most recent meta-analysis from the CDC did little to resolve the debate.*

**By: Cary Groner**

Stephen B. Thacker, MD, isn't used to getting hate mail. As director of the epidemiology program office at the Centers for Disease Control and Prevention (CDC) in Atlanta, Thacker spends most of his time assessing research, evaluating its implications for policy, and writing the occasional paper. So he was taken aback this year when, as lead author of a meta-analysis of studies on the impact of stretching on injury risk,<sup>1</sup> he started getting flamed.

People who advocate stretching were outraged at the paper's conclusion that stretching appeared to be neither particularly helpful nor harmful, according to Thacker. On the other side were those who felt the CDC had gone weak in the knees and should have slammed the practice.

"At CDC we encourage physical activity," Thacker said. "We want people to do things that have been documented to prevent injury, which includes interventions that improve balance, strength, and conditioning. We just don't want people depending on stretching, thinking they'll be all right."

### Healthy skepticism

Even defining stretching can be complex, because physical therapists and trainers promote different approaches depending on their own preferences, experience, and perceived needs of the athlete (see table, page 22).

Thacker's paper makes clear why athletes and performers should be skeptical of stretching's alleged benefits. For example, several investigators found little evidence to support injury prevention by stretching immediately before or after events, and determined that the practice may negatively affect performance.<sup>2-5</sup>

Other studies have found that stretching decreases muscle strength for anywhere from 10 minutes to 24 hours,<sup>6,7</sup>-a drop that increases injury risk in itself-and that passive stretching adversely affects jumping ability and plantar flexion.<sup>8,9</sup> Increased flexibility also appears to decrease running economy and peak performance.<sup>10-12</sup>

Duane Knudson, PhD, a professor of biomechanics at Chico State University in Chico, CA, has conducted extensive research into stretching and comes down on the side of the naysayers, even though several of his own studies suggest that stretching has little effect one way or the other.<sup>14-16</sup> Knudson raised questions about the purported merits of stretching in a 1999 paper in the *Journal of Physical Education, Recreation & Dance*, as well.<sup>17</sup> There he pointed out the difference between static flexibility-measured by the limits of joint motion-versus dynamic flexibility, which refers to how quickly resistance (tension) increases in stretched muscles.

Regular stretching does increase static flexibility, which is important in activities such as dance or gymnastics, where performers exceed normal motion ranges. However, the gain may be due more to increased "stretch tolerance," or the ability to be comfortable in those extended ranges, than to actual decreases in muscle stiffness, Knudson reported.

He also noted that the literature doesn't support the notion that increases in static flexibility prevent injury. For one thing, more mobile joints tend to be less stable, and the most flexible athletes have higher injury rates.<sup>18</sup> Some stretching techniques may also increase risk by stretching ligaments or creating hazardous loading patterns. And no research has documented ranges of motion related to minimized injury risk.

Although little is known about the long-term effects of stretching on dynamic flexibility, it does affect a muscle's viscoelastic properties in the short run. What remains unclear is whether this is beneficial, neutral, or harmful. Overall, Knudson concluded, "light to moderate muscle actions of gradually increasing intensity are more appropriate than stretching as warm-up activities for most sports." He added, however, that for those who

need a range of motion beyond the norm-gymnasts, dancers, or divers-stretching during the warm-up may be necessary.

"I'm generally of the belief that unless you're doing a sport where you need a lot of flexibility-or you're a very inflexible person-you don't need to stretch," Knudson said recently. "There is just an overwhelming amount of evidence that you make yourself weaker."

### **Eccentrics stand out**

Other researchers have had similar results but are somewhat more equivocal in their conclusions. Joel Cramer, PhD, assistant professor of kinesiology at the University of Texas at Arlington, has investigated the effects of static stretching on the vastus lateralis and rectus femoris, two muscles in the quadriceps group.<sup>19,20</sup>

"We found that static stretching seems to decrease the muscle's ability to produce force at both slow and fast velocities," Cramer said.

According to new data he and his team presented in June at the annual meeting of the American College of Sports Medicine, the acute effects of static stretching may be mode-specific, affecting isometric and concentric force production, but not eccentric force production.<sup>21</sup> (Eccentric force would be, for example, extending the arm while holding a barbell; concentric force would be raising the barbell to the shoulder; isometric force would be holding it in place.)

"We know that there is this decrease in concentric and isometric force production as a result of static stretching," Cramer added, "but what we really want to know is why."

The question arises due to the intriguing discovery that stretching one leg weakens both, implying that more than mechanical forces are at play. One theory is that a central nervous system mechanism is invoked.

Cramer doesn't feel as if he has enough information to recommend sweeping changes in training methods, regardless.

"Our studies suggest that these decreases in force production are so small that this may be a nonissue in actual practice," he said. "This fall we're going to conduct a longer study to see if regular static stretching (versus preexercise stretching alone) may avoid some of these deleterious effects."

### **Different approaches**

Ian Shrier, MD, PhD, a past president of the Canadian Academy of Sport Medicine and currently director of the epidemiology consultation service at the Sir Mortimer B. Davis Jewish General Hospital in Montreal, has earned a reputation for speaking bluntly about the issue.

"Most people believe that if you stretch immediately before exercise, it prevents injury and improves your performance," Shrier said. "Both of those are wrong. Lots of studies show that stretching right before exercise decreases the amount of force you can produce and how high you can jump."

Though it doesn't seem to have much effect on running speed, he added.

In a 2000 article in the British Journal of Sports Medicine concluding that preexercise stretching didn't prevent injury unless it was combined with an overall warm-up,<sup>23</sup> Shrier made several key points. For one, most injuries occur during eccentric contractions rather than concentric ones-and eccentric actions typically cause damage within the normal ROM, suggesting that stretching isn't likely to prevent such injuries. He also pointed out that stretching often increases pain tolerance, which in itself can increase injury risk for the simple reason that athletes may not be aware when they're hurting themselves.

But Shrier acknowledged that when stretching is done as part of a comprehensive program, the situation changes.

"Where most people mess up is by lumping stretching before exercise with stretching in general," he said. "If you stretch regularly, but not immediately before exercise, you actually increase your force, increase the amount you jump, and increase your speed. My guess is that if you stretch three or four times a week, you'll see benefits, and I personally believe that in the future people will say that it prevents injury-though the jury's out on that."

### **Fitting the stretch to the activity**

It's illustrative of the tenor of the broader argument that Malachy McHugh, PhD, claims friendship with Shrier, then laughingly claims to disagree with most of what Shrier says, then proceeds to agree with him on several issues including this last one.

McHugh, director of research at the Nicholas Institute of Sports Medicine and Athletic Trauma at Lenox Hill Hospital in New York, has published several studies of the effects of stretching on muscle elasticity. One found that muscle stiffness may be a risk factor for postexercise damage,<sup>24</sup> but others have suggested that the relationship of flexibility to performance may depend on which sport is studied.<sup>25</sup>

Nevertheless, McHugh thinks preexercise stretching is valuable as part of an overall warm-up. He noted that most people stretch to avoid muscle strains, and that little research has focused on its effects in sports with a high incidence of strains, such as soccer or football.

The rationale for strain prevention is that stretching makes the muscle more compliant, he said, which has implications for force production and injury prevention.

"We think a more compliant muscle has a greater functional range of motion, meaning the longer muscle should be able to produce more force," he said. "Usually at longer muscle lengths you lose strength because there is less overlap of your cross-bridges-the force-generating part of the muscle. But if you make a muscle a little more compliant, you can get more cross-bridge overlap and generate more force at the longer length. The muscles adapt rapidly, which is why a workout that makes you sore one week doesn't do so the next."

McHugh also offered an intriguing theory about the nature of strength loss after an acute bout of stretching. In some sports, such as sprinting, athletes must push their muscles almost to the point of failure.

"Maximal performance and injury risk might be complementary," he said. "The safety window might get smaller and smaller. As a result, if there's a small decrease in the amount of force you can produce, it might have a protective effect."

However, viewed in the context of reports from Cramer (that static stretching doesn't reduce eccentric force production) and Shrier (that most injuries occur during eccentric contractions), McHugh may need some evidence to back this up.

Overall, McHugh believes that the activity should determine the flexibility required-and that in many cases, stretching in some form is essential.

"In a lot of sports, dance and gymnastics in particular, you have to have the range of motion to perform your task," he said. "If dancers don't warm up and stretch, they won't be able to get their bodies into the positions required. Hurdlers have to have flexible hamstrings or they're not getting over the hurdle. But for a long-distance runner, tighter hamstrings are actually beneficial. A lot of other sports fall in between, and that's where the controversy lies."

### **Another kind of performance**

When it comes to activities such as dance, performance doesn't just mean power and speed, of course; it carries connotations of artistry. And in this, consensus emerges among the factions.

"Say a ballet dancer has a vertical jump of 23 inches," Shrier said. "If she stretches before her performance and it drops to 22 inches, nobody in the audience is going to notice. But she might feel that it is easier, less

strenuous, and that she can hold her form longer. So even though she isn't jumping as high, her performance is actually better. And though I don't think stretching needs to be part of most warm-ups, the rest of warm-up is extremely important. I'm not saying the ballerina should go out there cold."

Ruth Solomon agrees. Professor emeritus at the University of California, Santa Cruz, Solomon has been a dancer and dance trainer all of her professional life. She has published dozens of books, monographs, and journal articles about training and injury prevention, and is a member of the board of the International Association for Dance Medicine & Science.

She is often shocked when she walks into dance studios to teach for the first time and sees dancers stretching on a cold floor.

"I say, 'Please don't do that!' and explain that we'll stretch in the middle and at the end of class," she said.

According to Solomon, stretching must be an integral part of the warm-up process.

"As long as the blood is coursing through the body, the oxygen is flowing through the muscles, and the muscles are warm-then you can stretch," she said. "But not before. If you don't stretch and strengthen together, you'll have a weak muscle. The strength must balance the stretch if you want to control your movements."

Solomon explained that dancers are at risk for injury partly because dance demands such extended ranges of motion. Moreover, ballet dancers typically do exercises such as developpees and grand battements that develop their quadriceps, but may neglect the hamstrings. The resulting strength imbalance puts extra stress on the knee joint.

"If the muscles are really stretched out, the ligaments may not be able to protect the joints," she said. "So you get unstable joints, particularly knees, and you may get hyperextension and ligament tears."

Proprioceptive neuromuscular facilitation stretches are now favored in the dance community because they both strengthen and lengthen muscles, Solomon said.

### **A holistic view**

Because dancers do get injured, however, it's helpful to have physical therapists available who understand the injuries, how best to rehab them, and how to prevent recurrence. Rocky Bornstein, PT, was a dancer for 25 years before going into practice at Westside Dance Physical Therapy in New York.

Although Bornstein understands the necessity of isolating muscle groups to measure biomechanical forces, as in the studies described earlier, from a practical perspective she must consider her patients more holistically.

"Dancers tend to have a lot of laxity in their joints, a lot of range of motion, so in some cases strengthening may be more of an issue than stretching," she said. "If you have a joint that is not biomechanically lined up, the muscles that move it will be working overtime to compensate. Stretching the muscle without addressing the joint won't help."

For Bornstein, it's also critical to address how certain muscle groups affect the whole body. These data are typically missing from clinical trials because they are hard to measure, but perplexing results such as those reported by Knudson (where complex motions seemed to nullify the weakening effects of stretching) or by Cramer (where unilateral stretching had bilateral effects) highlight the issue's importance.

"Muscle lengths affect other joints in the body," Bornstein said. "People with short hamstrings who don't stretch them are going to break down somewhere else, probably in the lower back. We stretch our pectorals not just to lengthen them, but to alleviate upper back or cervical strain. It's allowing joints to move in the best way possible-and that's not necessarily the joint directly attached to the muscle."

Consensus begins to emerge when it comes to long-term stretching regimens.

"Dancers should stretch when their bodies are warm," Bornstein said. "That would not be right before you go out to perform. For that, you want to increase your circulation, be warm and ready and viable. Afterward, when the muscle has been worked really hard, is a better time to stretch."

As noted, Shrier supports this notion.

"Think of stretching like weight training," he said. "If you do it regularly, you get stronger. It's just that nobody does an exhausting workout right before they compete."

"I think he's exactly right," Knudson said when told of this remark. "Studies of strength and weight training in combination with stretching show that stretching doesn't diminish the effects. Some people who stretched did a little better."

It's apparent that the extent to which stretching is incorporated into warm-ups will depend on the individual and the activity, but it's reassuring to know that professional opinions may be converging. And who knows?-as time goes on, Stephen Thacker at the CDC may even get a little less hate mail.

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## References

1. Thacker SB et al. The impact of stretching on sports injury risk: a systematic review of the literature. *Med Sci Sports Exerc* 2004;36(3):371-78.
2. Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sports Med* 1999;9:221-27.
3. Weldon SM and Hill RH. The efficacy of stretching for prevention of exercise-related injury: a systematic review of the literature. *Man Ther* 2003;8:141-50.
4. Herbert RD and Gabriel M. Effects of stretching before and after exercising on muscle soreness and risk of injury: a systematic review. *Br Med J* 2002;325:468-70.
5. Knudson DV, Magnusson P, McHugh M. Current issues in flexibility fitness. *Pres Council Phys Fitness Sports* 2000;3:1-6.
6. Fowles JR, Sale DG, MacDougall JD. Reduced strength after passive stretch of the human plantar flexors. *J Appl Physiol* 2000;89:1179-88.
7. Kokkonen JA, Nelson AG, Cornwell A. Acute muscle stretching inhibits maximal strength performance. *Res Q Exerc Sport* 1998;69:411-15.
8. Cornwell AG et al. Acute effects of passive muscle stretching on vertical jump performance. *J Hum Mov Stud* 2001;40:307-24.
9. McCue BF. Flexibility measurements of college women. *Res Q* 1953;24:316-24.
10. Craib MW, Mitchell VA, Fields KB. The association between flexibility and running economy in sub-elite male runners. *Med Sci Sports Exerc* 1996;28:737-43.

11. Glem GW, Stachenfeld NS, Nicholas JA. The influence of flexibility on the economy of walking and jogging. *J Orthop Res* 1990;8:814-23.
12. Rosenbaum D and Henning EM. The influence of stretching and warm-up exercises in Achilles tendon reflex activity. *J Sports Sci* 1995;13:481-90.
13. Pope RP et al. A randomized trial of preexercise stretching for prevention of lower-limb injury. *Med Sci Sports Exerc* 2000;32(2):271-77.
14. Noffal GJ, Knudson D, Brown L. Effects of stretching the upper limb on throwing speed and isokinetic shoulder torques. (Presented at ACSM 2004)
15. Knudson D et al. Acute effects of stretching are not evident in the kinematics of the vertical jump. *J Strength Cond Res* 2001;15(1):98-101.
16. Knudson D, Mache M, Kotte J. Stretching has no effect on free throw shooting accuracy. (Presented at ACSM 2004)
17. Knudson D. Stretching during warm-up: do we have enough evidence? *JOPERD* 1999;70(7):24-27.