# Myths and Truths of Stretching

## Individualized Recommendations for Healthy Muscles

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**In Brief:** Stretching recommendations are clouded by misconceptions and conflicting research reports. This review of the current literature on stretching and range-of-motion increases finds that one static stretch of 15 to 30 seconds per day is sufficient for most patients, but some require longer durations. Heat and ice improve the effectiveness of static stretching only if applied during the stretch. Physicians should know the demands of different stretching techniques on muscles when making recommendations to patients. An individualized approach may be most effective based on intersubject variation and differences between healthy and injured tissues.

Despite limited evidence, stretching has been promoted for years as an integral part of fitness programs to decrease the risk of injury (1-6), relieve pain associated with "stiffness" (5), and improve sport performance (4-6). Many different stretching recommendations have come out of the medical literature, and new research has challenged some long-held concepts about common stretching practices. As a result, misconceptions and misinterpretations are common—not just among patients, but among healthcare professionals, as well. Thus, many clinicians are at a difficult crossroads when making sound recommendations to patients.

## Proposed Stretching Benefits

Proposed mechanisms are thought to be either (1) a direct decrease in muscle stiffness (defined as the force required to produce a given change in length) via passive viscoelastic changes or (2) an indirect decrease due to reflex inhibition and consequent viscoelasticity changes from decreased actin-myosin cross-bridging. Decreased muscle stiffness would then allow for increased joint range of motion.

New evidence suggests that stretching immediately before exercise does not prevent overuse or acute injuries (7,8). However, results from animal studies suggest that *continuous* stretching (ie, 24 hours per day) over days, compared with *intermittent* stretching of only minutes per day, outside of exercise periods may produce muscle hypertrophy (9-11), which could theoretically reduce the risk of injury (9,12). However, clinical research on stretching minutes per day is still inconclusive (13,14), and more research is needed before definitive conclusions can be made.

With respect to alleviating the pain associated with stiffness, the weight of the evidence suggests that the decrease in stiffness is not as important as the increase in "stretch tolerance" (15-17). Briefly, an increase in stretch tolerance means that patients feel less pain for the same force applied to the muscle. The result is increased range of motion, even though true stiffness does not change. This could occur through increased tissue strength or analgesia; however, increased stretch tolerance that occurs immediately after stretching must be caused by an analgesic effect because tissue strength does not increase during 2 minutes of stretching. Unfortunately, evidence of a possible analgesic effect is recent, and the underlying mechanism is unknown. After weeks of stretching, increases in stretch tolerance could theoretically occur because stretch-induced hypertrophy may increase tissue strength (9-11), and/or an analgesia effect may be present.

## A Search for Answers

Despite the controversies mentioned previously, stretching still decreases pain and may provide substantial benefits if used under appropriate conditions. However, the problem remains on how to choose an appropriate stretching protocol. Most authors now believe ballistic stretching (ie, bouncing) is dangerous (4-6,18). Time recommendations for holding a stretch vary between 10 and 60 seconds (5,19-24). Clinicians are also faced with choosing a method that may improve the effectiveness of stretching: superficial heat, superficial ice, deep heat, and warm-up (25-30).

To determine which stretching techniques are most effective, we reviewed all studies cited on MEDLINE and SPORTDiscus that compared stretching protocols for increasing range of motion. We chose range of motion as the end point because it is the tangible objective most people use when they stretch and because most studies have not addressed true muscle stiffness.

We addressed the following questions: (1) How long and how many times should a stretch be performed to obtain maximum benefit?, (2) Does temperature alter the effectiveness of stretching?, and (3) Which stretching method is most effective: static, ballistic, or proprioceptive neuromuscular facilitation (PNF) stretching?

Our review includes only studies of range of motion involving healthy muscle-tendon units—not diseased or abnormal capsular or ligamentous restrictions such as adhesive capsulitis that may require a different duration and frequency of stretching to increase range of motion (31,32). In addition, we could not find any papers that investigated the effects of stretching on injured patients. Any extrapolations of our review to injured patients should be performed with caution.

## Duration and Frequency

Before discussing the evidence on how long to hold a stretch, it is necessary to explain the concept of viscoelasticity. Stretches must be held to obtain maximum range of motion because muscles are not purely elastic, but rather viscoelastic. An elastic substance such as a rubber band lengthens for a given force and returns to its original length immediately upon release. The effect is not dependent on time. On the other hand, the flow and movement of a viscous substance such as molasses depends on time (33). A viscoelastic substance exhibits both properties. Therefore, muscle length increases over time if a constant force is applied (creep, figure 1A: not shown), or the force decreases over time if the muscle is stretched to a constant length and held (stress-relaxation, figure 1B: not shown). When the force is removed, the substance slowly returns to its original length. This is different from plastic deformation, in which a material such as a plastic bag remains permanently elongated even after the force is removed (33). Note that though stretches also affect tendons and other connective tissue, within the context of normal stretching, the stiffness of the overall motion is mostly related to the least stiff section (ie, resting muscle) and is minimally affected by the stiffness of tendons.

Patients are given many common protocols on stretch duration. In summary, for both the immediate (within 60 minutes) and long-term (over weeks) range-of-motion increases, research shows that one 15- to 30-second stretch per muscle group is sufficient for most people, but some people or muscle groups require longer duration or more repetitions. For immediate effects, stretching increases range of motion through both a decrease in viscoelasticity and an increase in stretch tolerance (ie, the analgesic effect previously discussed). With long-term stretching, viscoelasticity remains constant and the increased range of motion occurs only because more force can be applied to the muscle before the subject feels pain (ie, increased stretch tolerance).

**Immediate effects.** The immediate effects of stretching on range of motion have been studied in animals and humans. In isolated rabbit extensor digitorum and anterior tibialis muscles that were stretched for 30 seconds, viscoelastic effects increased muscle length until the fourth stretch (34). These results are consistent with those of human hamstring muscles that showed decreased stiffness with five repeated stretches (35).

However, Madding et al (24) found that increased hip abduction range of motion did not differ between 15, 45, or 120 seconds of stretching. Although these results may appear contradictory, viscoelasticity may vary by muscle group. In support of this theory, Henricson et al (27) found that muscles differed in their response to heat plus stretching. If true, the optimal duration and frequency for stretching may also vary by muscle group. Alternatively, range of motion in humans might be primarily limited by pain (15-17). If this theory is true, any smaller benefits obtained from decreased viscoelasticity with longer-duration stretches would be overshadowed by the large changes in range of motion from stretch-induced analgesia (stretch tolerance).

**Long-term effects.** The long-term effects of stretching on range of motion have been studied in humans only. After 6 weeks, individuals randomized to stretch for 30 seconds per muscle each day increased their range of motion much more than those who stretched 15 seconds per muscle each day. (A small increase in range of motion in the 15-second group was not statistically significant.) No further increase was seen in the group that stretched for 60 seconds (19).

In another study conducted over 6 weeks, the same researchers (22) found that one hamstring stretch of 30 seconds each day produced the same results as three stretches of 30 seconds. However, the results of Borms et al (36) appear to contradict these findings because 10-second stretches were as effective as 20- or 30-second stretches. Closer inspection of Borms' data, however, reveals large variation among individuals, and the study was performed over 10 weeks instead of 6 weeks. If one examines the data for trends, it appears that the 20-second and 30-second groups reached a plateau after 7 weeks, but the 10-second group increased gradually over the entire 10 weeks. Therefore, 30-second stretches are likely to achieve the maximum benefit quicker (within 6 to 7 weeks) than 10-second stretches, but the two programs eventually achieve similar results by 10 weeks.

**Rationale for individualized programs.** The above studies support the use of 30-second stretches as part of a general fitness program. This may be appropriate for group exercise classes in which one would want to use a duration that would benefit most individuals—similar to the recommended dietary allowance for vitamins and minerals. However, physicians and physical therapists usually treat individuals rather than groups.

In the animal study (34) that showed maximum benefit with four stretches, response varied depending on the individual experimental muscle. Consequently, some muscles must have achieved maximum benefit after two to three stretches, whereas others required five to six stretches. In human long-term studies, some individuals gained much range of motion with only 15 seconds of stretching, while others gained very little with 45 seconds (24).

Finally, all of the current research has been done on healthy tissue. Because muscle fatigue decreases viscoelasticity (37), it is reasonable to predict that injuries (with torn tissue, deposition of scar tissue, tissue reorganization, and muscle atrophy and weakness) will also change viscoelasticity, though the direction of the change is not clear. Therefore, healthcare professionals should be cautious about extrapolating these results to injured athletes, who may require longer stretches to increase range of motion. (See "Safety Concerns in Stretching," below.)

Rather than give everyone the same stretching recipe, we prefer to individualize our prescription to account for intersubject variation and differences between healthy and injured tissues. We advise patients to stretch until they feel a certain amount of tension or slight pulling associated with this length, but no pain. As the stretch is held, stress-relaxation occurs, and the force on the muscle decreases. When patients feels less tension because of changes in viscoelasticity and an analgesic effect, they can then simply increase the muscle length again until they feel the original tension. The second part of the stretch is held until patients feel no further increase.

If patients return for follow-up and have not gained any range of motion, and they are not overstretching (forcing a stretch, causing muscle spasm or pain), intersubject variability cited above may be the reason, and the clinician should consider recommending that the stretch be held longer. The effectiveness of this approach, however, remains to be tested.

## Temperature Effects

In summary, passive warming of a muscle before stretching or icing during the stretch can be used to increase the range of motion but will not prevent injury. Patients who include an active warm-up period prior to stretching obtain the greatest range of motion. Contrary to popular belief, warm-up performed without stretching does not increase range of motion.

Most of the research in this area has been done on animals using passive warming devices such as heat lamps. Research in humans often uses activity to warm the muscle, but activity affects the muscle in many ways—for example, calcium release and motor unit recruitment patterns—besides simply raising the temperature. This may explain the different results observed in animals and humans.

**Passive warm-up and icing.** Several studies examined the effect of temperature on range of motion. When applied before a static stretch, neither heat nor ice significantly affected the range of motion during active knee extension—a test of hamstring range of motion—when compared with stretching alone (38). Though heat alone did not improve range of motion, stretch plus heat was superior to stretch alone with respect to increases in hip flexion, abduction, and external rotation (27); shoulder range of motion (30); and triceps surae range of motion (25). Ice applied during a static stretch was the most effective method for increasing range of motion during a passive static stretch (29), but only when applied during the earlier stages of the stretch (30). Cold application during PNF stretching did not improve range of motion above the normal PNF technique (26).

In summary, despite some conflicting results, applying either ice or heat during a static stretch increases the range of motion compared with static stretch alone, but it has no effect during PNF stretches. Because ice and heat both increase range of motion and decrease pain, but have opposite effects on stiffness, the mechanism for the increased range of motion is probably analgesia rather than decreased stiffness.

**Active warm-up.** Most people believe that the light activity performed during warm-up will increase muscle temperature, decrease muscle stiffness, and increase range of motion. Animal studies consistently show a decrease in stiffness if the muscle or tendon is preheated (39-41). However, the range of temperatures studied is usually outside the normal physiologic range in humans (39-41).

In humans, the effectiveness of active warm-up to decrease stiffness appears to be related to the type of warm-up exercise and the muscle tested. For example, running appears to decrease the stiffness of the calf muscles (42) but not the hamstring muscles (43); running had no effect on range of motion in these studies. Stretching added after warm-up decreases hamstring muscle stiffness (range of motion not reported); however, the effect lasts less than 30 minutes, even if exercise continues after stretching (43). In the only study that measured the effect of cycling, hamstring or quadriceps range of motion did not change, although ankle range of motion increased (stiffness not measured ) (44). In another study, 15 minutes of cycling increased passive hip flexion and extension (stiffness was not measured) (45), but the pelvis was not properly stabilized during range-of-motion measurement.

Although activity by itself does not have a major effect on range of motion, studies consistently show greater range-of-motion increases after warm-up followed by stretching than after stretching alone (42,44). This research has probably been the basis for the recommendation to always warm up before stretching. The problem is that most people interpret it to mean that stretching before exercise prevents injuries, even though the clinical and basic science research suggests otherwise (7,8). A more precise interpretation is that warm-up prevents injury (46-49), whereas stretching has no effect on injury (7,8). Therefore, if injury prevention is the primary objective (eg, recreational athletes who consider performance a secondary issue) and the range of motion necessary for an activity is not extreme, the evidence suggests that athletes should drop the stretching before exercise and increase warm-up.

## Which Method Is Most Effective?

In general, PNF stretching has resulted in greater increases in range of motion compared with static or ballistic stretching (26,50-56), though some results have not been statistically significant (57-59).

Of the different types of PNF techniques, the agonist-contract-relax method (the hip flexors, including quadriceps muscles, actively stretch the hamstrings, followed by a maximal quadriceps contraction and passive holding) appears superior to the contract-relax method (muscle contraction followed by passive stretching) (50,54-56), which appears superior to the hold-relax technique (isometric contraction with resistance gradually applied over 9 seconds) (50,54-56,60).

For those who prefer the simplicity of static stretching, one study (61) reported that static stretching (continuous stretching without rest) is superior to cyclic stretching (applying a stretch, relaxing, and reapplying the stretch), whereas two studies (62,63) suggested no difference. All of these studies involved stretching the hamstring muscles, and methodological reasons for the discrepancy were not apparent. More research is needed before definitive conclusions can be made.

## Take-Home Points

Many of the different proposed protocols for stretching have some support from the published literature. The major points for clinical practice are:

- Heat, ice, and warm-up all increase the effectiveness of stretching to increase range of motion, but only warm-up is likely to prevent injury.
- Although one 30-second stretch per muscle group is sufficient to increase range of motion in most healthy people, it is likely that longer periods or more repetitions are required in some people, injuries, and/or muscle groups.
- Individuals should determine a strategy for themselves by simply holding a stretch until no additional benefit is obtained.
- Though PNF stretching is the most effective technique for increasing range of motion, the mechanism is an increase in stretch tolerance, and the muscle actually undergoes an eccentric contraction during the stretch. The increased analgesia may aid in performance but theoretically increases the risk of injury when compared with static stretches.

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## Safety Concerns in Stretching

Although the main objective of this article was to compare the effectiveness of different stretching regimens to increase range of motion, we also feel it is important to discuss safety. Follow-up studies have not investigated the safety of different stretching modalities, so all comments here and in the medical literature are theoretical.

Some clinicians believe ballistic stretching is dangerous because the muscle may reflexively contract if restretched quickly following a short relaxation period (ie, eccentric or lengthening contraction) (1), and eccentric contractions are believed to increase the risk of injury (2,3). We agree with this concern, but it is important to add that ballistic stretching is more controlled than most athletic activities. Therefore, it is likely to be much less dangerous than the sport itself if performed properly and not overly aggressively.

The original theory that proprioceptive neuromuscular facilitation (PNF) techniques increase range of motion through reciprocal muscle inhibition, thereby decreasing electromyographic activity, was first disproved in 1979 (4,5) and again more recently (6,7). Muscles are electrically silent during normal stretches until end range of motion nears. Surprisingly, PNF techniques increase electrical activity and muscle stiffness during the stretch (4,5,7), despite the observed increase in range of motion. This means that the muscle eccentrically contracts during the PNF stretch, which most clinicians would consider more dangerous than electrically silent muscle. PNF and ballistic stretching both cause an eccentric contraction, but PNF stretching appears to have a more pronounced analgesic effect. From a safety viewpoint, it does not seem prudent to "anesthetize" a muscle during or immediately before it is required to perform higher-risk eccentric contractions. The benefits of the greater increase in range of motion should be balanced against a theoretical increase in the risk of injury. (There are no data on risk of injury with PNF stretching.)

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