Stretching—A Research Retrospective

by Len Kravitz, PhD on Oct 26, 2009

An in-depth analysis of the myths, truths and controversies.

A primary function of muscles is to create tension and produce force for movement of the body's skeletal system. The intrinsic property of muscles and joints to go through a full or optimal range of motion (ROM) is referred to as flexibility. It is developed through the use of various stretching procedures. Presently, uncertainty exists about some proposed benefits of flexibility, including its effect on injury avoidance, muscle soreness prevention, muscular strength training and performance improvement. This review article will attempt to clarify these issues with existing evidence-based science and will present a current research update on this component of fitness.

About the Author

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Flexibility Determinants

Andersen (2006) suggests that the foundational determinants of flexibility are a multifactorial cluster of elements (see Figure 1). It is also acknowledged that flexibility is a characteristic specific to each joint or group of joints.

AGE

Flexibility has been shown to decrease up to 50% with age in some joint areas. From a base of 1,000 elderly men and women, Bassey et al. (1989) showed that shoulder abduction decreased gradually and consistently with age and was about 25% less in these elderly subjects compared with norms for a younger population. Einkauf et al. (1987) examined the changes in spinal mobility for 109 women aged 20–84 years. The results indicated that spinal mobility decreased with age by 20%, 33% and 50% for anterior flexion, lateral flexion and extension, respectively. Brown and Miller (1998) showed that sit-and-reach ROM decreased approximately 30% for women between 20 and 70-plus years of age. Buckwalter (1997) proposes that a gradual deterioration with age in the cell function within cartilage, ligaments, tendons and muscles is the mechanism for this loss of flexibility. Misner and colleagues (1992) add that collagen, a main constituent of connective tissue, becomes dense (and stiffer) with aging. However, Bassey and associates suggest that this loss of motion can be minimized with regular stretching and ROM exercise.

GENDER

It has been shown that due to minor differences in joint structures and connective-tissue anatomy, women have slightly greater ROM than men for most joint motions. With a sample of 190 male and female subjects ranging in age from 18 to 88 years, Bell and Hoshizaki (1981) measured 17 joint actions in eight specific joints. The female subjects did have greater overall flexibility than the males. In an assessment of the upper-body joints (shoulder, elbow, wrist, trunk and neck) of a group of 41 subjects (22 young male and female subjects aged 25–35 years and 19 mature male and female subjects aged 65–80 years), Doriot and Wang (2006) also found females to have significantly greater ROM in several joint actions. However, these researchers note that the effect of gender on ROM is much less than that of age.

PHYSICAL ACTIVITY

For the most part, active individuals have greater flexibility in the joints they regularly use than in their inactive counterparts. Voorrips et al. (1993) confirmed with a population of 50 mature women (mean age 71 years) that those subjects who regularly did more walking had greater flexibility in the hip and spine (assessed by sit-and-reach test) than their less active counterparts. Kerrigan et al. (2001) declare that these data suggest a very meaningful application with fall prevention. Their comparison of 16 elderly subjects (8 men and 8 women; average age 77 years) with a history of falling to 23 healthy nonfallers (10 men and 13 women; average age 73 years) showed an association between hip tightness and more falls. The authors specifically recommend hip extension stretching as a necessary intervention for fall prevention. Misner and colleagues (1992), in a long-term study with 12 women aged 50–71 years, showed that regular exercise (15–30 minutes of stretching and 30–60 minutes of walking or water aerobics) 3 times per week for 5 years increased shoulder and hip ROM significantly (3%–22% in various joint actions). Exercise also helped the subjects perform activities of daily living more efficiently. Indeed, ACSM (2006) recommends that preventive and rehabilitative exercise programs should include activities that promote the maintenance of flexibility.

Stretching Methods to Increase Flexibility

There are several known methods (and variations within each method) to increase flexibility. These include passive, dynamic, ballistic and static stretching, contract-relax stretching, proprioceptive neuromuscular facilitation (PNF) techniques and Resistance Stretching®. (The figures demonstrate the methodology of each, yet readers should be aware that there are numerous variations and techniques that can be used within each method.)

Passive stretching is usually performed with a partner who applies a sustained stretch to a relaxed joint. It requires close communication between client and trainer, along with a slow application of the stretch in order to prevent a forceful manipulation of the body segment and possible injury. The client is not actively involved in the stretch.

Dynamic stretching incorporates active-ROM movements that tend to resemble sport- or movement-specific actions. For instance, a volleyball player might do some shoulder flexion and extension actions prior to a game. The rhythmic nature of a controlled dynamic stretch has a functional application owing to its similarity to the primary movement task. Dynamic stretching is often incorporated in the "active" phase of class warm-ups.

Ballistic stretching involves a bouncy approach to reach the target muscle's motion endpoint. A concern with ballistic stretching is that it is often performed in a jerky, bobbing fashion that may produce undesirable tension or trauma to the stretched muscle and associated connective tissues. It may produce a potent stretch reflex that will oppose the muscle lengthening.

Static, or Hold stretching is probably the most commonly used flexibility technique and is very safe and effective. A muscle or muscle group is gradually stretched to the point of limitation (a mild, even tension) and then typically held in that position for 15–30 seconds.

Contract-Relax and PNF stretching techniques were developed by Dr. Herman Kabat in the 1950s as part of his therapeutic work with patients suffering from paralysis and muscular diseases (Sharman, Cresswell & Riek 2006). There are several variations. The contract-relax method involves initially contracting the target muscle, then relaxing and stretching it with an assist from a partner or an applied force (i.e., towel or rope). A variation (contract-relax agonist-contract method) involves performing a contraction of the *opposing* muscle during the stretching phase to take the target muscle to a new, farther motion endpoint (Sharman, Cresswell & Riek 2006). Traditional PNF techniques involve doing the stretches in diagonal or spiral motions to promote movement through various planes of motion, while contract-relax movement patterns tend to involve single-joint motion through one plane (see the sidebar "Proposed Mechanisms of PNF Stretching: The Controversy").

Resistance Stretching has gained much attention and interest. It focuses on contracting the target muscles as they are lengthened. In the first phase, the target muscles are placed in the shortened position. Then the client *contracts* the target muscle(s). While contracted, the muscles are taken through a full ROM (lengthened). So, Resistance Stretching incorporates a strengthening component through the entire ROM. In essence, it is a carefully performed *eccentric* contraction. The originators of Resistance Training incorporate some very detailed rotational patterns (to challenge the muscle in multiple planes).

Controversial Issues

The most controversial issues with flexibility include injury avoidance, muscle soreness prevention, impact on muscular strength training and performance improvement. Several hundred studies have been conducted on these topics (from randomized and controlled to general observation). To specifically address these questions, recent review articles published in influential, peer-reviewed publications were selected for this current discussion, as these review articles rigorously evaluate and summarize findings across a number of scientific studies and provide the overall "state of knowledge."

PRE-EXERCISE STRETCHING AND INJURY RISK

Perhaps one of the most exhaustive and comprehensive research reviews on this topic was completed by Thacker et al. (2004). The authors conclude that pre-exercise stretching does not prevent injury among competitive or recreational athletes. Thacker and colleagues support the proposal that this is due to an alteration in joint connective-tissue compliance (ability of the tissue to extend appropriately in response to applied pressure). In some cases, this alteration may lead to greater joint instability. They point out that studies incorporating a pre-exercise combination of resistance exercise, body conditioning and warm-up show promise for better injury prevention. Perhaps this will be a new direction for fitness professionals to pursue.

PREVENTING OR REDUCING MUSCLE SORENESS

Summarizing their findings, Herbert and de Noronha (2009) state that stretching before and after exercise has not been shown to impart any additional protection from muscle soreness. Therefore, stretching does not reduce some of the mechanisms of muscle soreness, including damage to the ultrastructure of muscle, accumulation of calcium ions, cell inflammation, swelling and activation of pain receptors.

IMPACT ON MUSCULAR STRENGTH

When viewing the acute (immediate) effects of stretching before strength training, Rubini, Costa and Gomes (2007) note that static and PNF stretching have shown decreases in *maximal* strength ranging from 4.5% to 28%. Yet most of this research used more than one stretching exercise for the same muscle group, with total stretching times of 120–3,600 seconds, which is much more than the recommended four stretches of 30 seconds, totaling 120 seconds, for optimal flexibility increases (ACSM 2006). Rubini, Costa and Gomes add that when the total flexibility session is shorter (30–480 seconds), the research shows little or no compromise from stretching right before maximal force production. Importantly (and practically), exercisers do not train daily to their maximal voluntary contraction, where compromises in strength are observed. Interestingly, Rubini and colleagues highlight that there is no scientific consensus in the research for the underlying mechanism explaining the force production loss in muscle after stretching.

IMPACT ON PERFORMANCE

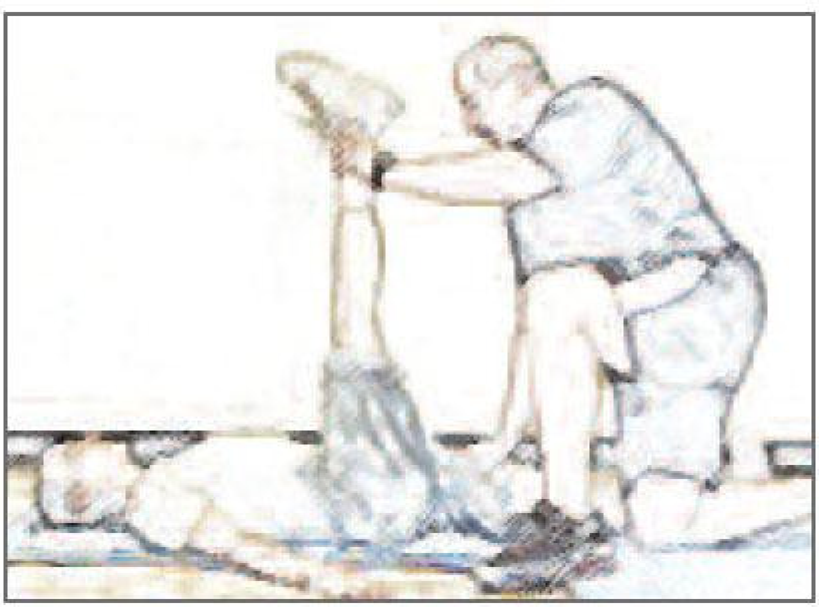
The studies center attention on the areas of jumping ability, torque (rotary force), running economy and maximal force production. Shrier (2004) reviewed 23 studies, which combined have included static, PNF and ballistic stretching techniques with both genders (from children through adults and untrained individuals through highly competitive athletes). The findings, supported by other reviews (Haff 2006), reveal that regular stretching, when performed at times other than *before* performance, may elicit positive long-term performance outcomes. However, preperformance stretching may educe (bring out; elicit) insignificant or negative performance outcomes.

Final Thoughts

This article symbolizes an important triumph for applied research. For many decades, coaches, athletes and others have touted numerous benefits of flexibility. As seen in similar disciplines, the practical beliefs of key pioneers often guide the field. However, as observed with flexibility, many of these beliefs have not proved accurate when challenged through the benchmark of scientific investigation. This does not minimize the importance of flexibility as a component of fitness, yet it better directs professionals who wish to incorporate it into program designs.

Figure 1. Determinants of Flexibility

Figure 2. Passive Stretching

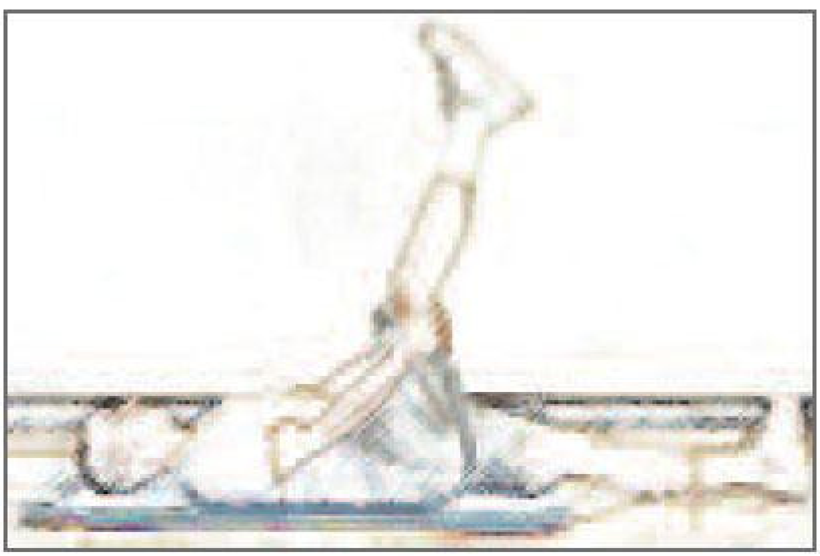


The personal trainer applies a slow stretch of the hamstrings. The client is not actively involved in the stretch.

Figure 3. Dynamic *or* Ballistic Stretching

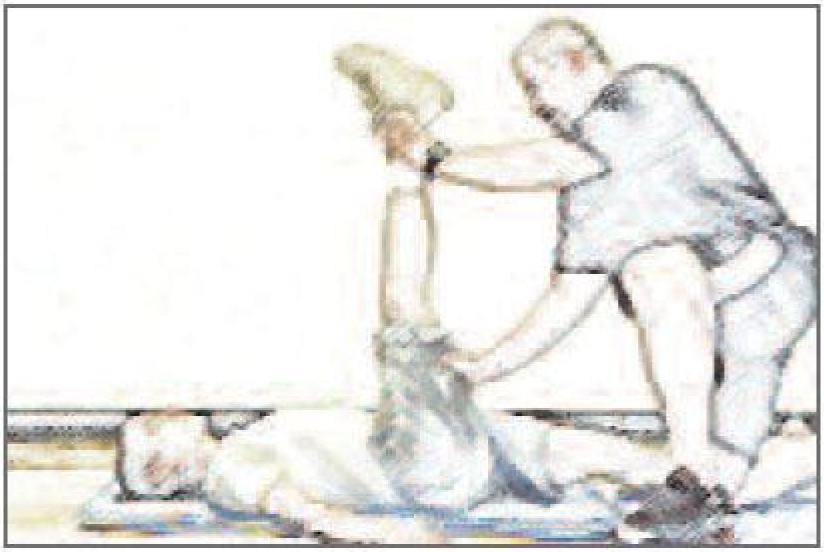
With dynamic stretching the client goes through a controlled active ROM. Ballistic stretching incorporates a rapid bobbing action from the start of the movement to the endpoint of motion.

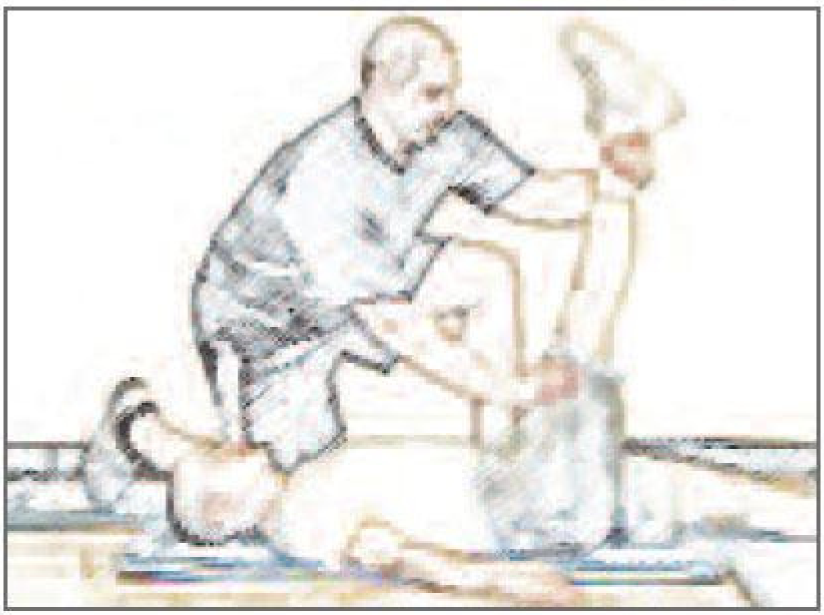
Figure 4. Static Stretching



The client actively brings the target muscle group to the point of limitation.

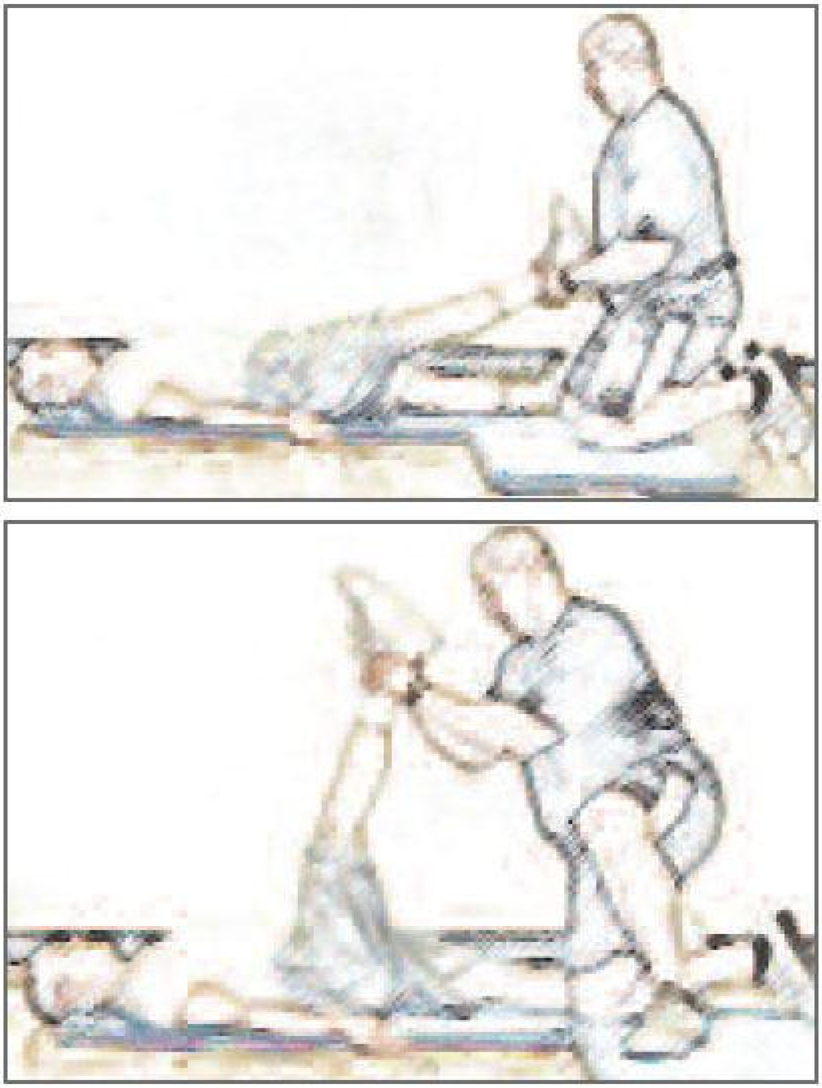
Figures 5 & 6. Contract-Relax & Contract-Relax Agonist-Contract *or* PNF Stretching





With contract-relax (Figure 5, top), the stretched target muscle group (hamstrings) is placed into a static contraction, followed by a relaxation. With contract-relax agonist-contract (Figure 6), the opposite muscle group (hip flexors) is contracted against applied resistance. At release, the client stretches to a “new” endpoint of motion. PNF stretching follows a similar technique, except that physical therapists additionally take the movements through various planes of motion.

Figures 7 & 8. Resistance Stretching



The client starts in a shortened position (Figure 7, top) against applied resistance (provided by the personal trainer). The trainer then takes the client's hamstrings through an eccentric action to the motion endpoint (Figure 8). The trainers who developed Resistance Stretching often go through different planes of motion with this type of stretching.

Top 10 FAQs About Flexibility

1. How long should you hold a stretch for flexibility improvement?
The American College of Sports Medicine (ACSM 2006) recommends holding a stretch from 15 to 30 seconds.

2. What is the optimal number of times to repeat a stretch?
According to ACSM (2006), 2–4 repetitions is optimal, as further repetitions do not elicit additional benefits.

3. How many days per week should someone stretch?
Each person differs, but ACSM (2006) suggests 2–3 days per week as a minimum, although 5–7 days per week of some type of stretching routine would be the ideal for most persons.

4. What is hypermobility syndrome?
Hypermobility syndrome is a congenital (present at birth but not necessarily hereditary) laxity of some ligaments and joints. It occurs most frequently in the knees, elbows, wrists, hands and ankles (Adib et al. 2005).

5. What are proprioceptors?
They are specialized nerves that communicate information about the musculoskeletal system to the central nervous system. Proprioceptors (also called mechanoreceptors) are the source of all proprioception, which is the perception of one's own body position and movement. Found in all nerve endings of the joints, muscles and tendons, the proprioceptors related to stretching are located in the tendons (Golgi tendon organs) and in the muscle fibers (muscle spindles).

6. What is the best flexibility method?
In a review of 27 peer- reviewed studies on ROM techniques, Thacker et al. (2004) noted that all methods have been shown to be very effective in improving ROM, with no clear best method. Several studies show proprioceptive neuromuscular facilitation (PNF) to be superior to static and dynamic, whereas other studies show equal effectiveness of several stretching methods (Haff 2006). However, Sharman, Cresswell and Riek (2006) contend that since PNF stretching improves passive and active ROM, it may provide additional functional benefits.

7. When doing PNF stretches, do you maximally contract the target muscle?
Conventionally, maximal contractions have been recommended because it was felt that the **Golgi tendon organs** (receptors in the tendons of muscle-tendon units) respond only to high forces. In fact, the Golgi tendon organs are sensitive to very low forces, and a contraction of as little as 20%–70% of maximal contraction will suffice (Sharman, Cresswell & Riek 2006). The lower intensity of contractions will help reduce the risk of any type of injury from the PNF stretching.

8. What is the best application of PNF stretching?
Evidence-based research provides the following recommendations (Sharman, Cresswell & Riek 2006):

- Duration of static contraction of the target muscle is 3–15 seconds.
- Contraction intensity of the target muscle is 20%–70% (see #7). The researchers note that there is evidence that progressive increases in intensity (within the 20%–70% range) may provide greater gains in ROM.
- No studies have investigated opposing muscle contraction intensity for PNF stretches in this phase.
- One complete repetition seems to be sufficient (i.e., *one* contract-relax or *one* contract-relax agonist-contract stretch).

9. Will using heat packs before stretching enhance ROM?
Knight and colleagues (2001) compared static stretching of the plantar-flexor muscles preceded by no warm-up, active exercise, hot packs (superficial heat before stretching) and ultrasound (deep heat before stretching) in 97 subjects (59 women, 38 men) who had limited dorsiflexion ROM. All experimental groups increased active and passive ROM, with the deep-heat intervention being the most effective.

10. What is the stretch reflex?
As a muscle is stretched, so is the muscle spindle (which runs parallel to muscle fibers). The muscle spindle records the change in length (and speed of length change) and transmits this signal to the spinal cord. This triggers the stretch reflex (also called the myotatic stretch reflex), which initially attempts to *oppose* the change in muscle length by causing the stretched muscle to contract. The more sudden the change in muscle length, the stronger the contraction is. Thus the muscle spindle attempts to protect the muscle from injury. One of the reasons for holding a stretch for a sustained period of time (15–30 seconds) is that the muscle spindle gradually becomes accustomed to the new length and reduces its opposing signaling, thus allowing for greater muscle lengthening.

Viscoelastic Muscle Properties

- Muscle is composed of viscous (sarcoplasm), elastic (muscle filaments) and nonelastic (connective tissue) fibers.
- The elastic properties of muscle are very similar to a spring (Chalmers 2004) that lengthens and returns to its natural resting length in direct proportion to applied and released force.
- A muscle's passive resistance to the elongation of a stretch is referred to as **stress relaxation.** With sustained holding of the stretch, the muscle will gradually elongate, a viscoelastic property known as **creep.**
- When a stretch is sustained, there is a reduction (about 30%) in the stress relaxation, causing a transitory relaxation in muscle tension (Chalmers 2004). Greater increases in muscle length occur within the first 15 minutes after completing three, 30-second static stretches (Woods, Bishop & Jones 2007).
- Viscoelastic properties of muscle show that a muscle will provide its greatest resistance to stretch when the stretch is applied rapidly—hence the scientific rationale for slow stretching of a muscle (Chalmers 2004).
- With regular, long-term stretching, there are proposed viscoelastic changes in the surrounding connective tissue and tendon (attached to the target muscle). These changes slightly increase the elasticity of the muscle-tendon unit (Kubo et al. 2001).
- Other cellular and molecular biological changes occur in muscle, including the addition of more sarcomeres (structural units of a muscle cell) to muscle (De Deyne 2001).

Flexibility Guidlines

Here are some useful stretching guidelines. Note that *not all guidelines are appropriate for all methods.* For example, the Resistance Stretching technique involves muscle contracting throughout the ROM, which is quite different from traditional stretching methods.

1. Assess your client's flexibility to pinpoint strengths and weaknesses.
2. Design a stretching program that enables clients to boost their physical activity and/or sport participation.
3. Make sure muscles are appropriately warmed up before taking them through any muscle stretching technique.
4. Perform stretching at least 2–3 times per week, and ideally 5–7 days per week.
5. Stretch all major muscle groups as well as opposing muscle groups.
6. Focus on the muscles involved in the stretch, minimizing the movement of other body parts.
7. Hold stretches for 15–30 seconds.
8. Stretch to the limit of movement, not the point of pain. This is referred to as the "endpoint" of the stretch.
9. Keep the breathing slow and rhythmic while holding stretches. Have clients *exhale* slowly as they extend to the endpoint of the stretch. As they exhale, the diaphragm and thoracic-cavity muscles are relaxing, thus promoting a more effective relaxation of the target muscles.
10. Stretch the muscles in various positions, as this may improve the overall ROM at the joint.
11. Incorporate some stretches that attempt to relax the target muscle before going into the stretch. This can be done by taking the muscle out of a weight-bearing and/or body stabilization position prior to the stretch.
12. Stretch after each vigorous workout to encourage mind and body relaxation.
13. If the stretch yields pain, back off the movement and make sure the stretching technique is correct. It may be necessary to try another position or a different stretching exercise (or method).

Warm-Up vs. Stretching

Warm-Up

- provides essential preparation needed for vigorous exercise
- increases blood flow to working tissues, velocity of nerve impulses to muscles and delivery of oxygen and foodstuffs for energy liberation
- enhances removal of waste products from muscle
- enhances muscles' metabolic properties (reactions to synthesize ATP) and mechanical efficiency of contraction and force production
- includes pre-exercise injury prevention component that increases elasticity of the muscle-tendon unit
- should be at relative intensity of 40%–60% of person's VO2max and induce some mild sweating without fatigue

Stretching

- increases ROM about joint or group of joints
- may elicit positive long-term performance outcomes when done at times other than *before* performance
- enhances flexibility (intrinsic property of muscles and joints to go through full or optimal ROM)
- is effective intervention for prevention of falls
- assists in more effective performance of daily living activities

Sources: Thacker et al. 2004; Safran et al. 1988; Woods, Bishop & Jones 2007; Kerrigan et al. 2001; and Misner et al. 1992.

Proposed Mechanisms of PNF Stretching: The Controversy

The proposed mechanisms of PNF stretching involve two neurophysiological phenomena referred to as autogenic inhibition and reciprocal inhibition (Sharman, Cresswell & Riek 2006).

Autogenic inhibition, (aka “reverse myotatic reflex”) refers to a reduction (or inhibition) in excitability of a contracting muscle. This inhibitory input comes from the Golgi tendon organs, which are sensory receptors in the tendons (of the target muscle). Thus, in the contract phase of the contract-relax PNF stretch, the target muscle is contracted, which elicits autogenic inhibition. This is followed by a stretch to the target muscle (thus having inhibited neural input and allowing for greater ROM).

Reciprocal inhibition involves the agonist-contract phase of the contract-relax agonist-contract PNF method. When the opposing muscle contracts, it is felt that inhibitory messages are signaled to the target muscle to relax (thus allowing for a lengthened stretch). The thought is that the more the muscle can be relaxed through *autogenic inhibition* and *reciprocal inhibition,* the more the muscle can be lengthened, and the greater the flexibility gains (Haff 2006).

In a contemporary review article, Gordon Chalmers (2004) argues that the historical explanation of autogenic and reciprocal inhibition is convenient, but research in recent decades denotes that a much more complex neuromuscular response is in play. According to Chalmers, the research shows that possible viscoelastic properties of muscle (see the sidebar “Viscoelastic Muscle Properties”) and an unexplained phenomenon known as **stretch tolerance** are possible mechanisms observed with acute changes in ROM from PNF stretching.

Shrier (1999) posits that stretching may elicit an analgesic effect, resulting in an increased pain threshold (tolerance) without actual changes in muscle stiffness. It is this hypothesis that is referred to as stretch tolerance. Clearly, more sophisticated research is needed to identify and understand this new stretching hypothesis.

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