

PART I

UNDERSTANDING FLEXIBILITY

Flexibility is the ability to move muscles and joints through their full ranges of motion. Throughout this text, the term *flexibility* refers to the degree of “normal” motion. In contrast, stretching refers to the process of elongating connective tissues, muscles, and other tissues. Flexibility and stretching exercises fall into several basic categories depending on the manner in which a muscle is stretched. Several of these more common flexibility categories are as follows:

1. Static flexibility relates to range of motion (ROM) about a joint with no emphasis on speed during stretching; hence, static flexibility is the result of static stretching. A common example is a “split.”
2. Ballistic flexibility is usually associated with bobbing, bouncing, rebounding, and rhythmic motion. In ballistic stretching, momentum of a moving body or limb is used to increase the ROM forcibly. Consequently, the risk of injury is greater. An example of a ballistic stretch is swinging your arms out to the side so that the momentum is responsible for the increased ROM.
3. Dynamic or functional flexibility refers to the ability to use a range of joint movement in the performance of a physical activity at either normal or rapid speed. In contrast to ballistic stretching, it includes no bouncing or jerky movements. Dynamic or functional flexibility directly corresponds to the specificity of the stretching process as it relates to the activity. Dynamic or functional flexibility has the highest correlation to sport achievement.
4. Active flexibility refers to a range of motion accomplished by the voluntary use of one’s muscles without assistance. An example of active flexibility is an athlete slowly raising and holding the kicking leg to a 100-degree angle. Active flexibility may be static or dynamic.

Research has proven that flexibility does not exist as a general characteristic but is specific to a particular joint and joint action (Merni et al. 1981); that

is, range of motion is specific to each joint in the body. For instance, an athlete may be flexible in the hips but tight in the shoulders, or tight in the right hip but flexible in the left hip. Attempts to correlate flexibility to body proportions, body surface area, skinfold, and weight have yielded inconsistent results (Alter 1996).

A review of the literature (Alter 1996) demonstrates that flexibility is specific to a given group of sports as well as to a given joint, a given side, and a given speed. Even within sport groups, particular patterns of flexibility are related to frequent or unique joint movements in those activities, events, or positions. For example, a baseball pitcher's dominant shoulder possesses an increased range of external rotation over his other shoulder (Cook et al. 1987). Earlier research found that throwing velocity was significantly related to the range of external shoulder rotation (Sandstead 1968). Similarly, Cohen et al.

(1994) demonstrated that numerous flexibility measures—including dominant wrist flexion, dominant shoulder forward flexion, and dominant shoulder internal rotation at zero degrees of abduction—are directly related to tennis serve velocity. Therefore, flexibility training focusing on improving a joint's ROM must be specifically tailored to the needs of the individual athlete and the sport in which he or she is participating.

BENEFITS OF STRETCHING

- Stretching can optimize an athlete's learning, practice, and performance of many types of skilled movements. For example, a high jumper using the straddle technique requires additional flexibility in the adductors, groin, and hamstrings.
- Stretching can increase an athlete's mental and physical relaxation.
- Stretching can promote development of body awareness.
- Stretching can reduce risk of joint sprain or muscle strain.
- Stretching can reduce risk of back problems.
- Stretching can reduce muscle soreness.
- Stretching can reduce the severity of painful menstruation (dysmenorrhea) for female athletes.
- Stretching can reduce muscle tension.

THE BENEFITS OF STRETCHING

Flexibility is developed when connective tissues and muscles are elongated through regular, proper stretching. In contrast, flexibility diminishes over time when these tissues are not stretched or exercised. Some of the many reasons why athletes should want to improve their flexibility through stretching exercises are listed to the left.

However, stretching is only beneficial when done properly. For example, athletes need to make stretching a regular part of their training program and devote several minutes to stretching each day to see results. Athletes also need to stretch gradually, slowly, and using the correct technique to avoid injuring themselves during stretching. Just as there is more than one way to achieve a set goal, there is more than one stretch to enhance flexibility. The 311 stretching exercises detailed in part IV of this book allow you to add variety to your stretching routine.

HOW THE BODY RESPONDS TO STRETCHING

Two of the many intricate parts that make up the human body are the skeletal and the muscular systems. Your bones help make up the specialized support system of your body's skeleton, and to perform their support function, they must be held together. Joints are points at which two or more bones connect, and the connections are performed primarily by ligaments and assisted by muscles and tendons.

Muscle Structure

The primary function of muscle tissue is to produce movement through its ability to contract and develop tension. Muscles are attached to bone by tendons. The place where a muscle attaches to a relatively stationary point on a bone is called the origin, and the end of the muscle that moves with the bone is known as the insertion. When a muscle contracts, it develops tension that is transmitted to the bones by the tendons, and movement takes place; thus, movement is caused by the interaction of the muscular and skeletal systems.

Muscles are obviously important to stretching and developing flexibility. Muscles come in various shapes and sizes, but all are composed of progressively

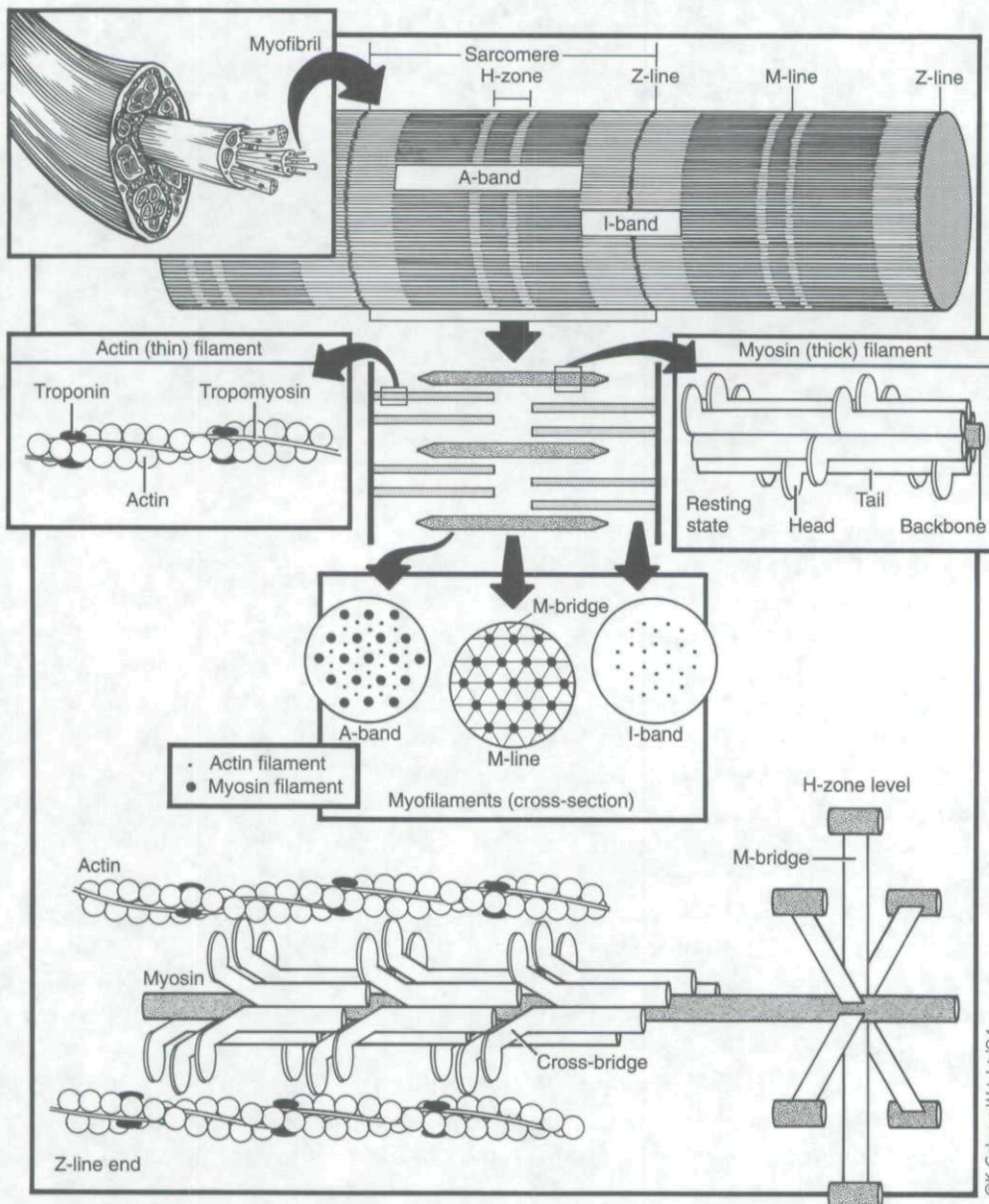


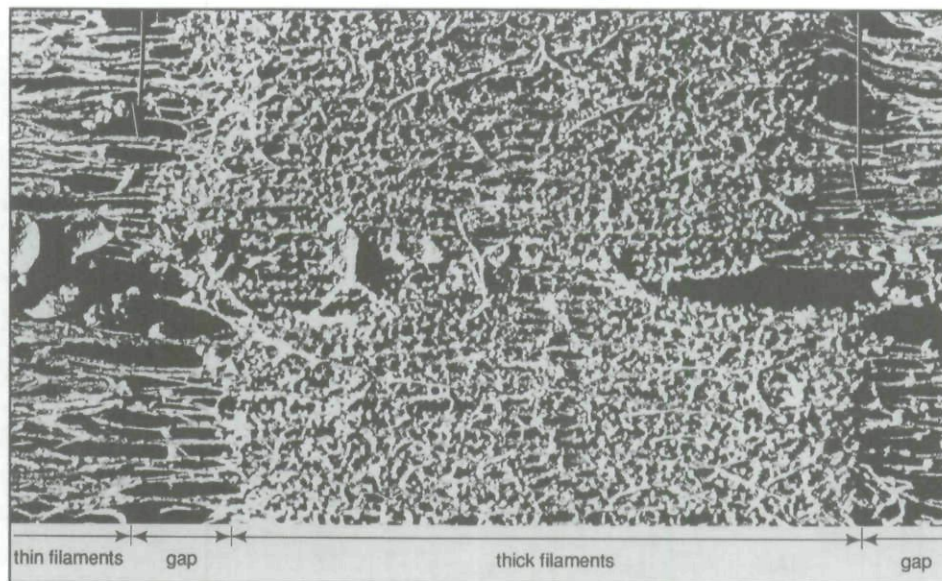
Figure 1 Organization of skeletal muscle tissue from the gross to the molecular level.

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smaller units (figure 1). The *myofibrils* are the elements of your muscles that contract (shorten), relax, and elongate (stretch) and are composed of functional units or muscle cells called *sarcomeres* which are represented in figure 1 as repeating light and dark patterns. Sarcomeres were originally thought to be composed primarily of just thick (myosin) and thin (actin) filaments, but the existence of a third connecting filament (titin) is now recognized. Electron microphotographs clearly demonstrate the presence of these and other structures (figure 2).

Figure 2 Examples of connecting filaments (titin) in overstretched frog muscle, prepared by freeze-fracture, deep-etch method. Thick filaments (center) do not terminate; they give way to thinner connecting filaments (arrows), which run out of the field toward the Z-line. Thin filament tips, seen at edges of figure, do not overlap the thick filaments.

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A diagrammatic summary of the sarcomere's principal structures is shown in figure 3. These filaments and structures are significant because they determine how sarcomeres elongate and consequently influence an athlete's flexibility. It is important to understand that the most important component of muscle related to flexibility is the connective tissue that envelops and surrounds the muscle at its various levels of organization.

At present, muscles are hypothesized to function in a way partly described by Huxley's sliding filament theory (Huxley and Hanson 1954). Basically, the muscle fibers receive a nerve impulse that causes the release of calcium ions stored in the muscle. In the presence of adenosine triphosphate (ATP), the "fuel" of the muscles, the calcium ions bind with the actin and myosin filaments to form an electrostatic bond. The bond can be likened to two opposing magnets attracting each other. As a result of this bond, the muscle fibers shorten and develop tension. When the muscle fibers no longer receive nerve impulses, they relax. The recoil of the elastic elements restores the filaments to their former uncontracted lengths.

In contrast, when the muscles are stretched, the actin and myosin reverse the interlinking effect that takes place during contraction. Research has demonstrated that, at first, stretch comes easily to the actin and myosin filaments. As stretch continues, the titin filament takes up more and more of the displacement; hence, the titin filament is primarily responsible for the sarcomere's extensibility and resistance to stretch. This resistance is called "resting tension." If stretching continues, eventually the sarcomere's integrity is compromised and it ruptures.

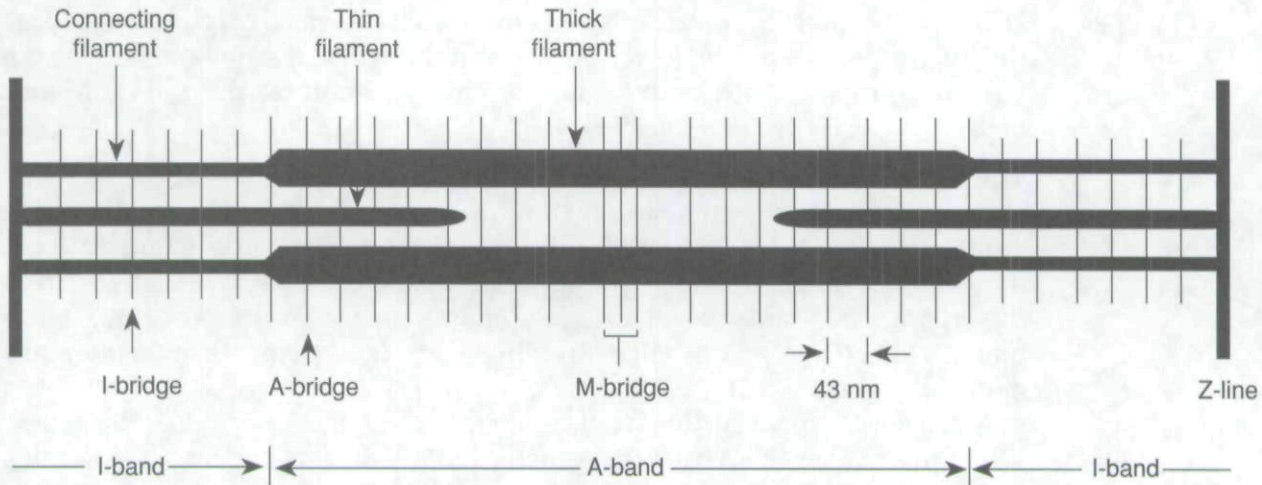


Figure 3 Diagrammatic summary of the sarcomere's principal structures.

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Research has demonstrated that a sarcomere can be stretched to 150 percent of its resting-state length (Wang et al. 1991). Obviously, then, the contractile elements (filaments) of the sarcomere cannot be a limiting factor in flexibility when the muscle is relaxed. This degree of potential sarcomere elongation is significant for all athletes whose sports require an enhanced range of motion. Thus, if the muscle is relaxed (and there is no structural limitation), and if the connective tissues are properly stretched, virtually any athlete can achieve even a full split. Although this degree of flexibility is not required of most sports, many disciplines require one to possess such a capacity (e.g., gymnastics, figure skating, the martial arts). Keep in mind that the most important component related to flexibility is the connective tissue that envelops and surrounds the muscle at its various levels of organization (i.e., muscle fiber, bundle, and whole muscle). This tissue consists of the endomysium, perimysium, and epimysium, explored later in this section.

Skeletal (voluntary) muscles possess two distinct types of nerve-fiber receptors: the Golgi tendon organs (GTOs) and muscle spindles. These receptors are important because they can sense stretch. The GTOs are located almost exclusively at muscle-tendon or muscle-aponeurosis junctions and not within tendons. An aponeurosis refers to the tendinous sheaths that usually extend along and deep into the belly of the muscle. The GTOs monitor all degrees of muscle tension but are most sensitive to tension forces generated by muscle contraction. Consequently, this monitoring is extremely relevant for specific stretching techniques that use contractions of the muscle being stretched (i.e., proprioceptive neuromuscular facilitation [PNF], described later). Extremely intense stretching is necessary to activate GTOs.

Muscle spindles are miniature muscle fibers and nerve endings in a fusiform-shaped spindle encapsulated by a sheath of connective tissue that run parallel to the muscle fiber. These smaller muscle fibers are referred to as *intrafusal* because of their location within the spindle. The muscle spindles have two types of sensory endings: primary and secondary. Primary endings respond to both a phasic (dynamic) and tonic stretch response. In contrast,

secondary endings respond only to tonic stretch. A phasic response measures the length plus rate or velocity of the stretch; hence, such responses play a vital role during ballistic or dynamic stretching. In contrast, the tonic response measures the length of a muscle.

The Stretch Reflex. The stretch reflex is a basic operation of the nervous system that helps maintain muscle tone and prevent injury. The stretch reflex is a muscle's response to a sudden, unexpected increase in its length. Stretching a muscle lengthens both the muscle fibers and the muscle spindles, and this change in shape of the muscle spindles results in firing of the stretch reflex. The muscle that is being stretched contracts to minimize the increase in its length.

A classic example of the stretch reflex is the knee jerk, or patella reflex. When the patella (kneecap) tendon is given a light tap, the muscle spindles that run parallel to the muscle fibers are stretched and change shape, causing the muscle spindles to fire. This sends a message to the spinal cord. Completing the reflex arc, the spinal cord sends an impulse to the quadriceps (thigh muscles) and causes them to contract; the quadriceps shorten, taking the tension off the muscle spindles.

Beginning athletes generally should avoid strenuous ballistic or bouncing types of stretches, because this type of stretching increases the likelihood of injury and soreness and makes muscular tension increase in the very muscle you are attempting to stretch. This tension makes it more difficult to stretch connective tissues. Hence, for the safest stretching, relax the parts of the muscle that perform contraction and employ slow or static stretching to reduce the probability of initiating the stretch reflex. However, for most sports, ballistic or dynamic stretching is an essential component of the training regime. This topic is discussed below.

Reciprocal Innervation. Muscles usually operate in pairs of agonists and antagonists, so that when one set of muscles is contracting, the opposing muscles are relaxing. The muscles most directly involved in bringing about a movement are called the agonists or prime movers. Muscles that slow down or oppose the prime movers are called antagonists. The grouping of coordinated and opposing agonistic and antagonistic muscles is called reciprocal innervation. For example, when you flex your arm at the elbow by contracting your biceps, your triceps muscle, which normally extends your arm at the elbow, must relax. If it didn't, the two muscles would be pulling against each other, preventing movement. Similarly, the biceps muscle must relax when you attempt to extend your arm.

Reciprocal innervation is accomplished by cooperation between the nerves supplying any antagonistic pair of muscles. When one of the pair receives an impulse to contract, the other relaxes because it does not receive an impulse to cause contraction. It is therefore inhibited at the same time that its opposing muscle contracts. By taking advantage of this phenomenon, you can induce relaxation in the muscles you want to stretch. For example, to stretch your hamstrings, contract your quadriceps while in a modified hurdler's stretch (see part IV, stretch # 50). Reciprocal innervation will make your hamstrings relax. Consequently, you should feel greater ease as you lean forward into the stretch.

The Inverse Myotatic Reflex. Perhaps you have experienced a sudden and involuntary relaxation of your muscles when stretching. This is due to the

inverse myotatic reflex. The GTOs were thought to be solely responsible for this reflex; however, today we believe that the GTOs along with other receptors are involved in this reflex (Moore 1984).

The GTOs are thought to operate in the following manner. When the intensity of a muscular contraction or stretch on a tendon exceeds a certain critical point, an immediate reflex occurs to inhibit the muscular contraction. As a result, the muscle immediately relaxes and the excess tension is removed. This reaction is possible only because the impulses of the GTOs are powerful enough to override the excitatory impulses of the muscle spindles. This relaxation is a protective mechanism—a safety device to prevent tendons and muscles from being injured by tearing away from their attachments.

However, this system is not fail-safe. We know that the effects of the GTOs can be counterbalanced by additional signals from higher centers of the central nervous system. This process of minimizing the influence of GTOs is referred to as disinhibition of the agonist motoneurons and is a result of athletic training (Brooks and Fahey 1987). The purpose of disinhibition is to push performance to the limits of tissue capacity. In extreme cases, disinhibition in activities such as wrist wrestling and weight lifting can result in torn muscles or tendons.

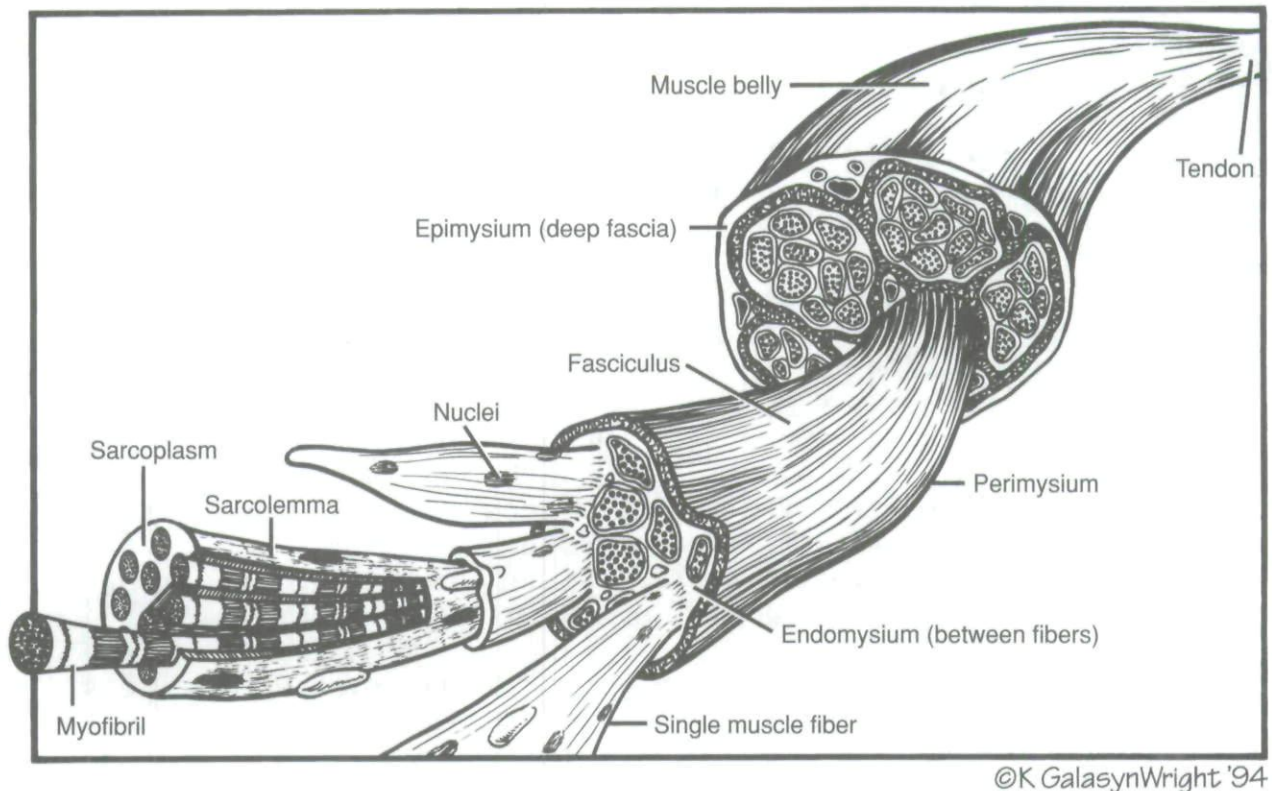
The inverse myotatic reflex has two important implications for stretching. First, it may explain why, when an athlete is attempting to maintain a stretching position that develops considerable tension in the muscle, a point is suddenly reached where the tension dissipates and the muscle can be stretched even farther. Second, by using a stretching strategy called the contract-relax technique (explained below), relaxation can be induced in muscles that are being stretched. For example, stretch a limb or muscle to the point where further motion in the desired direction is prevented by the tension of the antagonistic muscle. At this point, gradually build to a less than maximal contraction in the stretched muscles (antagonists) for 6 to 15 seconds. This will cause the GTOs to fire and initiate the inverse myotatic reflex. Then, move the joint through the gained range of joint motion. (Note, however, that there is greater risk with this procedure because it develops more tension in the muscle, which may result in soreness and injury.)

Connective Tissue

Connective tissue, which binds together to support the various structures of the body, is the body's most abundant tissue. Its functions include defense, protection, storage, transportation, and general support and repair.

Two types of connective tissue can significantly affect an athlete's range of motion: collagenous connective tissue and elastic connective tissue. The former is composed primarily of collagen and the latter of elastic tissue. Where collagenous fibers dominate, range of motion is restricted. Conversely, a dominance of elastic fibers allows a greater range of motion. Within limits, through flexibility training or rehabilitation, an athlete's tissues can be modified and their performance enhanced.

Technically, the term fascia designates all fibrous connective tissues not otherwise specifically named. Muscle fascia (sheaths) envelop and bind muscle fibers into separate groups. These sheaths are the endomysium, perimysium, and epimysium (figure 4). A muscle's resistance to stretch originates in the meshwork of these connective tissues; as you stretch, your connective tissues become more taut.



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Figure 4 Schematic drawing of a muscle illustrating three types of connective tissue: epimysium (the outer layer), perimysium (surrounding each fasciculus, or group of fibers), and endomysium (surrounding individual fibers).

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Of great interest to all athletes is the relative importance of various tissues in joint stiffness. The joint capsule (the sacklike structure that encloses the ends of bones) and ligaments are the most important factors, accounting for 47 percent of stiffness, followed by the muscle's fascia (41 percent), the tendons (10 percent), and the skin (2 percent) (Johns and Wright 1962). However, most efforts to increase flexibility through stretching should be directed at the muscle fascia for two reasons. First, muscle and its fascia have more elastic tissue, so they are more modifiable in terms of reducing resistance to elongation. Second, because ligaments and tendons have less elasticity than fascia, it is undesirable to produce too much slack in them. Overstretching these structures may weaken the integrity of the joints. As a result, excessive flexibility may destabilize the joints and increase an athlete's risk of injury. Because the connective tissues probably play the largest role in limiting an athlete's range of motion, they must be stretched properly, such as by following the directions in part IV of this book, to develop optimal flexibility.

Bones and Joints

Ultimately, an athlete's range of motion at a joint is restricted by both the bone and the joint structure. Just as the railroad track determines the route available to the train, so the shape and contour of the joint surfaces ultimately determine the movement. Pathways are further influenced by cartilage, liga-

ments, tendons, and other connective tissues that frequently serve as restraining factors.

The pelvic region exemplifies the correlation between bone and joint structure and range of movement (figure 5, *a* and *b*). Some of the structural characteristics of the female pelvis that differ from the male pelvis are these:

- Bones are lighter.
- Brim is rounder.
- Cavity is shallower and more capacious.
- Outlet is larger.
- Sacrosciatic notch is wider.
- Acetabula are farther apart.
- Subpubic angle is wider.
- Sacrum is wider and more curved.

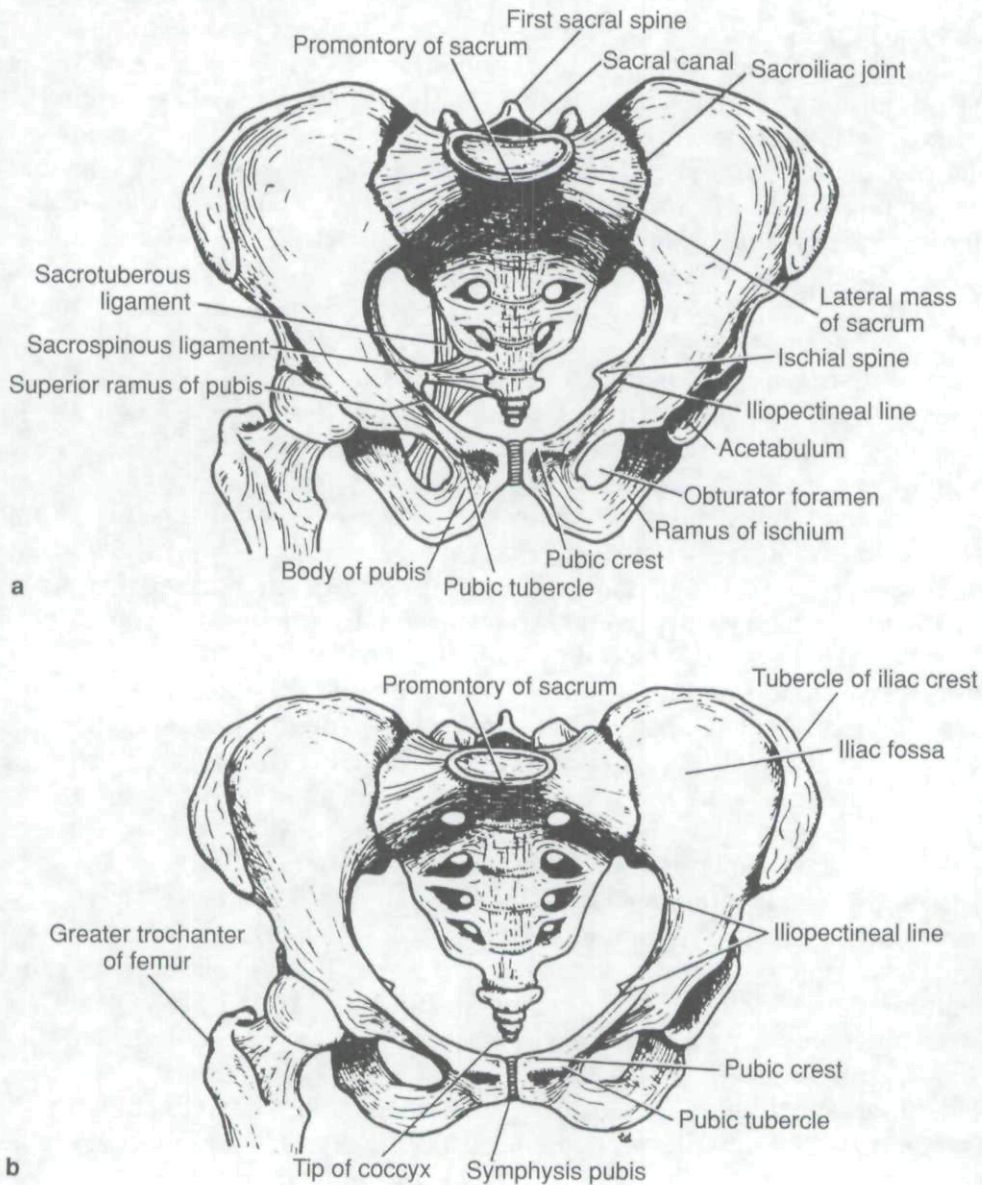


Figure 5 The male (*a*) and female (*b*) pelvis.

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It is important for athletes and coaches to understand that the female's pelvis generally allows a greater range of flexibility than the male's. The most significant structural reasons for a female's enhanced flexibility are broader hips and a less shallow pelvic cavity (acetabulum). In particular, the less shallow pelvis permits greater joint play and hence ROM in the pelvic region.

WHAT HAPPENS WHEN YOU STRETCH?

Several types of adaptation result from proper and regular stretching. First, as stated earlier, when a muscle is suddenly stretched, the stretch reflex is initiated and the muscle being stretched contracts. However, through training, the critical point at which the stretch reflex is initiated can be "reset" to a higher level. Consequently, your muscles relax farther into the stretch. Research in the field of neurophysiology has demonstrated adaptive plasticity in the central nervous system (Wolpaw and Carp 1990). Specifically, the magnitude of the spinal stretch reflex can be uptrained (increased), downtrained (decreased), or even trained to reverse the changed response. Wolpaw and Carp's study (1990) has even substantiated the hypothesis that altered reflex activity eventually modifies the plasticity of the spinal cord neural circuits.

Second, with increased stretching over time, the number of sarcomeres is thought to increase in series. These new sarcomeres are added onto the end of the existing myofibrils. Research has substantiated that an addition of sarcomeres is responsible for an increase in muscle length (Goldspink 1968; Williams and Goldspink 1971). However, additional research is needed to substantiate that an increase in the number of sarcomeres actually results from a traditional stretching program used in an athletic setting.

Third, with increased stretching over time the fascial sheaths encasing your muscles—the epimysium, endomysium, and perimysium (refer to figure 4)—may undergo semipermanent change in length. Other tissues adapting to the stretch are the tendons, ligaments, fascia, and scar tissue.

Fourth, stretching exercises are known to increase passive range of motion and extensibility of the hamstrings. However, research has also shown that stretching exercises do not make short hamstrings less stiff. Rather, increased extensibility is attributed to an increase in stretch tolerance (Halbertsma and Göeken 1994; Halbertsma, van Bolhuis, and Göeken 1996).

Fifth, research suggests that muscle cells may control and modulate stiffness and elastic limit coordinately by selective expression of specific titin isoforms (structural variants) (Wang et al. 1991); that is, muscles that express greater titin isoforms tend to initiate tension at longer sarcomere lengths, reach their elastic limit at higher sarcomere lengths, and develop the lowest tension. Such control and modulation may be influenced by training.

Sixth, stretching is thought to stimulate the production and retention of gel-like substances called glycoaminoglycans (GAGs). The GAGs, along with water and hyaluronic acid, lubricate connective tissue fibers, maintaining a critical distance between them. This prevents the fibers from touching one another and sticking together. As a result, excessive cross-linkages are not formed (figure 6) (Akeson, Amiel, and Woo 1980).

Seventh, x-ray studies (Nikolic and Zimmermann 1968) have demonstrated that training can modify the bone and joint structure in dancers; hence, range of motion can be enhanced, and stretching is one way to do this.

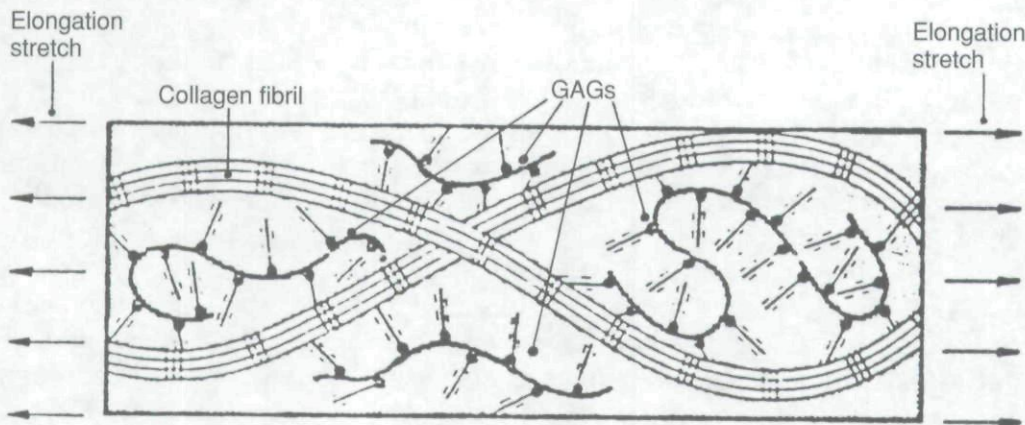


Figure 6 The action of GAGs. Stretch is applied to collagen fibrils, but the GAGs keep the fibrils separated and aligned.

Reprinted, with permission, from E.R. Myers, C.G. Armstrong, and V.C. Mow, 1984, Swelling, Pressure, and Collagen Tension. In *Connective tissue matrix*, ed. D.W.L. Hukin. (Deerfield Beach, FL: Verlag Chemie), 171.

Last, recent research suggests that mechanical stimulation (e.g., stretching or resistance training) of muscle and connective tissues may affect gene expression (Simpson et al. 1994; Sutcliffe and Davidson 1990). This, in turn, may modulate tissue variants and thus influence muscle and connective tissue extensibility.

STRETCHING TECHNIQUES

Stretching refers to the process of elongation. Stretching exercises are performed in a variety of ways, depending on your goals, abilities, and state of training. For example, a world-class gymnast or black belt in karate may perform more advanced stretches than individuals who are beginning stretching programs simply to improve their personal health and fitness. There are five basic stretching techniques: static, ballistic, passive, active, and proprioceptive.

Static Stretching

Static stretching involves stretching to the farthest point and holding the stretch. Splits are a good example of static stretching. This method of stretching is not only the safest, but also has been test proven for centuries by practitioners of hatha yoga as a means of enhancing flexibility. Other advantages are that it

- is simple to learn and easy to execute,
- requires little expenditure of energy,
- allows adequate time to reset the sensitivity of the stretch reflex,
- permits semipermanent change in length, and
- can induce muscular relaxation via firing of the GTOs if the stretch is sufficiently intense.

The major disadvantage of static stretching is its lack of specificity. During the early 1960s, the S.A.I.D. Principle, developed by Wallis and Logan (1964), put forth the idea that ideally athletes should develop their strength, endurance, and flexibility based on the principle of specific adaptation to imposed demands; that is, one should stretch at not less than 75 percent of maximum velocity through the exact plane of motion, through the exact range of motion, and at the precise joint angles used while performing skills in a specific activity. Research studies substantiate the concepts of sport specificity and the S.A.I.D. Principle. Because most activities and movements are dynamic in nature, static stretching does little to enhance coordination and does not offer optimal specificity in training. Remember, muscle has two types of receptors: The primary endings measure both velocity and muscle length, whereas the secondary endings measure length alone. Thus, dynamic stretching must be used to condition the primary endings for their desired response.

In addition, one study (Rosenbaum and Hennig 1995) suggested that it is advisable not to apply solely static stretching routines because of "a potentially impairing effect on muscle performance" (p. 489). Specifically, their research found stretching had a negative effect on active force production. A possible rationale for this negative effect may be due to mechanical characteristics changes of the damping ratio (the ability to absorb and dissipate shock loading) and mechanical stiffness (the ability to resist deformation) of soft tissues (Siff 1993a).

Ballistic and Dynamic Stretching

Ballistic stretching involves bobbing, bouncing, rebounding, and rhythmic types of movement. As mentioned earlier, in ballistic stretching, momentum is the driving force that moves the body or limb to forcibly increase the ROM. This technique is the most controversial stretching method because it can cause the most soreness and injury. Other disadvantages are that it

- fails to provide adequate time for the tissues to adapt to the stretch; and
- initiates the stretch reflex and thereby increases muscular tension, making it more difficult to stretch the connective tissues.

Based on the above disadvantages, athletes may choose to incorporate dynamic rather than ballistic stretching into their training regime. The key difference between ballistic and dynamic stretching is that the latter does not end with bouncing or jerky movements. Instead, the movements are under control. Research has demonstrated that both ballistic and dynamic stretching enhance flexibility; however, dynamic stretching develops optimum dynamic flexibility, essential for all sports. Remember, flexibility training must be velocity specific to condition and train the velocity-specific stretch receptors.

A safe ballistic (dynamic) stretching program has been developed by Zachazewski (1990). He recommends a progressive velocity flexibility program (PVFP) preceded by a warm-up. Then, over time, the athlete goes through "a series of stretching exercises in which the velocity and range of lengthening are combined and controlled on a progressive basis" (p. 228). This gradual program permits the muscle and musculotendinous junction to adapt progressively to functional ballistic movements, hence reducing the risk of injury. Zachazewski (1990; see figure 7) briefly describes the program as follows:

The athlete progresses from an environment of control to activity simulation, from slow-velocity methodical activity to high-velocity functional activity. After static-stretching, slow short end range (SSER) ballistic stretching is initiated. The athlete then progresses to slow full range stretching (SFR), fast short end range (FSER) and fast full range (FFR) stretching. Control and range are the responsibility of the athlete. No outside force is exerted by anyone else. (p. 228)

In contrast, Tom Kurz, a leading flexibility instructor, challenges the generally accepted belief that static stretching should be employed after an initial warm-up routine. He contends that "doing static stretches before a workout consisting of dynamic actions is counterproductive." Instead, he advocates using dynamic stretches first and static stretching when the major part of the workout is completed and it is time for cool-down (Kurz 1994).

Passive Stretching

Passive stretching is a technique in which you are relaxed and make no contribution to the range of motion. Instead, an external force is created by a manual or mechanical outside agent. Passive stretching is preferred when the elasticity of the muscles and connective tissues to be stretched (antagonists) restricts flexibility and for muscles or tissues undergoing rehabilitation. Among the advantages associated with passive stretching are the following:

- It is effective when the agonist (the primary muscle responsible for the movement) is too weak to respond.
- It is effective when attempts to inhibit the tight muscles are unsuccessful.
- It is preferred when the elasticity of the muscles to be stretched (antagonists) restricts flexibility.
- It allows stretching beyond one's active range of motion.
- It provides a reserve for increasing the joint's active mobility.
- Direction, duration, and intensity can be measured when more advanced stretching machines and modalities are used in rehabilitative therapy.
- It can promote team camaraderie when athletes stretch with partners.

Athletes need to recognize several disadvantages with regard to passive stretching. First, there is greater risk of soreness and injury if a partner applies the external force incorrectly. In addition, passive stretching may initiate the stretch reflex if the stretch is too rapid. Another important disadvantage is that the likelihood of injury increases with greater differences between the ranges of active and passive flexibility (Iashvili 1983) (figure 8). But perhaps most important for the athlete, research has demonstrated that passive

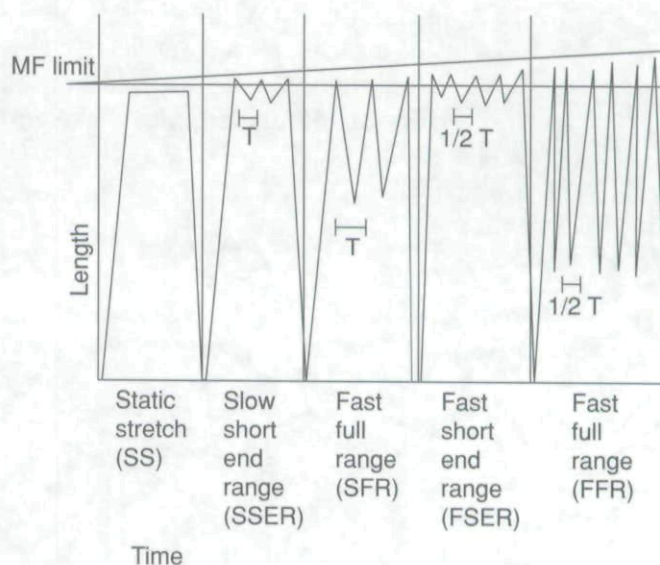


Figure 7 A progressive velocity flexibility program (PVFP). MF limit is the muscle flexibility limit of the muscle being stretched.

Reprinted, with permission, from J.E. Zachazewski, 1990, *Flexibility for sports*. In *Sports physical therapy*, ed. B. Sanders. (Norwalk, CT: Appleton & Lange), 234.

flexibility values have a lower correlation to the level of sport achievement than active flexibility (Iashvili 1983). The solution, then, is to develop your active flexibility also.

Active Stretching

Active stretching is accomplished using your own muscles and without any assistance from an external force. Active stretching can be divided into two major classes: free active and resistive. Free active exercise or stretch occurs when muscles produce movement without application of additional external resistance. An example of free active stretching is standing upright and slowly

lifting one leg to a 100-degree angle. In resistive active exercises, the athlete uses voluntary muscle contractions to move against an applied resistance. Using the previous example, a manual resistance or weight can be applied to the leg being lifted. Active stretching is preferred when the weakness of those muscles producing the movement (agonists) restricts flexibility.

Active stretching is vital to the athlete because it develops active (and potentially dynamic) flexibility, which in turn has been found to have a higher correlation with sport achievement than does passive flexibility (Iashvili 1983). As active stretching is most specific to a given discipline, it has the greatest potential value for the athlete. Moreover, active stretching may be easier to work into a stretching routine, as it does not require a partner or other equipment. The major disadvantages of active stretching are that it may initiate the

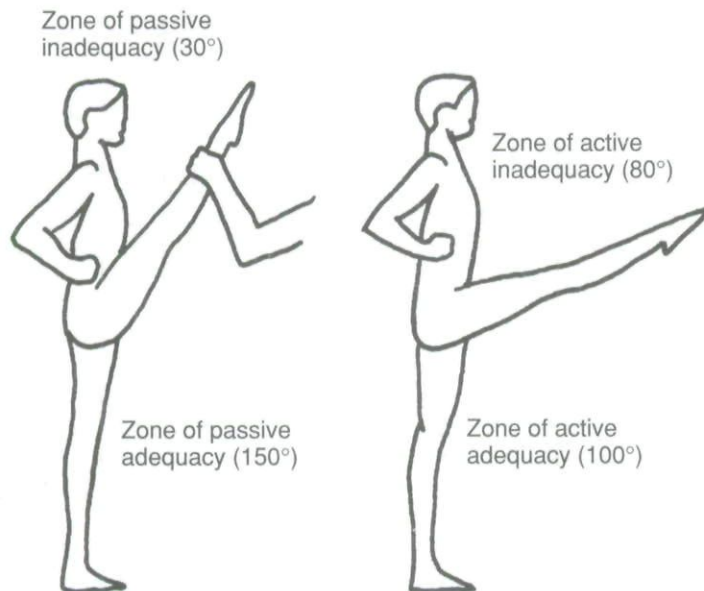


Figure 8 Flexibility zones.

Reprinted, with permission, from M.J. Alter, 1996, *Science of Flexibility*, 2nd ed. (Champaign, IL: Human Kinetics), 179.

stretch reflex and that it may be ineffective in the presence of certain dysfunctions and injuries such as severe sprains, inflammation, or fractures.

In recent years, a modified version called active-assisted stretching has become increasingly popular. With active-assisted stretching, the range of motion is completed by a partner or device (inner tube or towel) when one's limit of flexibility is reached. The advantage of this modified technique is that it can activate or strengthen the weak agonist opposing the tight muscle, help establish the pattern for coordinated motion, and allow stretching beyond one's active range of motion. Research is needed to quantify and substantiate claims of enhanced performance for athletes.

Proprioceptive Neuromuscular Facilitation

Proprioceptive neuromuscular facilitation is another broad strategy that can be implemented to improve your range of motion. A modified version of one of the PNF techniques is referred to in osteopathic medicine as a muscle energy technique. PNF was originally designed and developed as a rehabilita-

tive physical therapy procedure. Today, several different types of PNF are being used in the arena of sports medicine. Names and descriptions of PNF techniques vary according to source; therefore, comparisons are often difficult to assess. In this text, we have adopted the terminology and description of Moore and Hutton (1980). Two of the more prevalent PNF strategies in athletic training are the contract-relax and contract-relax-agonist-contract techniques.

Contract-Relax (CR) Technique. The contract-relax technique (also called hold-relax technique) starts with the athlete's tight muscle group (antagonist) in a lengthened position. Assume for the sake of illustration that your hamstrings are tight. The tight hamstrings are first gently stretched and gradually contract isometrically, building to a less than maximum effort for 6 to 15 seconds against a partner's resistance. As the contraction is isometric, there is no change in the muscle's length or movement of the joint. This contraction is followed by a brief period of relaxing the hamstrings. Then the partner slowly lengthens the tight muscle group (hamstrings) by passively moving the extremity through its gained range of motion (figure 9, *a* and *b*).

The rationale for the contract-relax technique is that the initial contraction of the antagonists (hamstrings) in the stretched position is thought to promote a subsequent relaxation phase of the same muscle. In part, this relaxation may be a result of the inhibitory activity from the GTOs. Still, it is

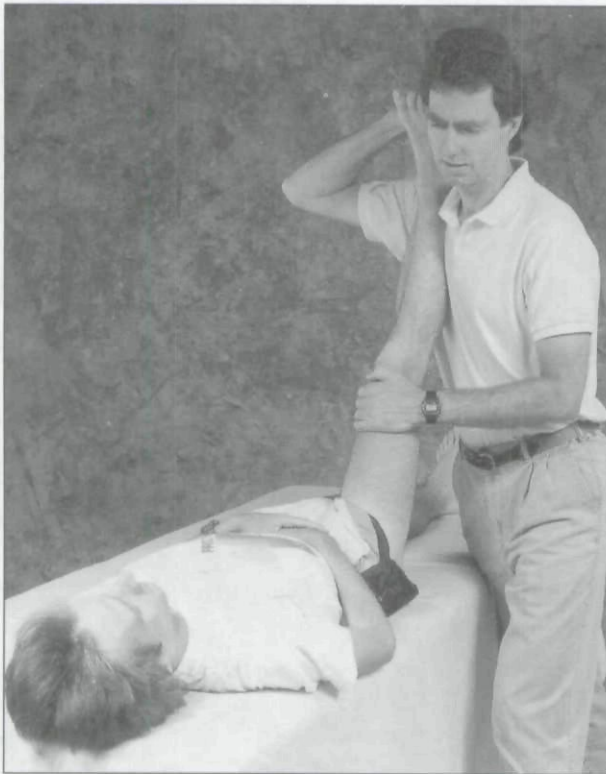
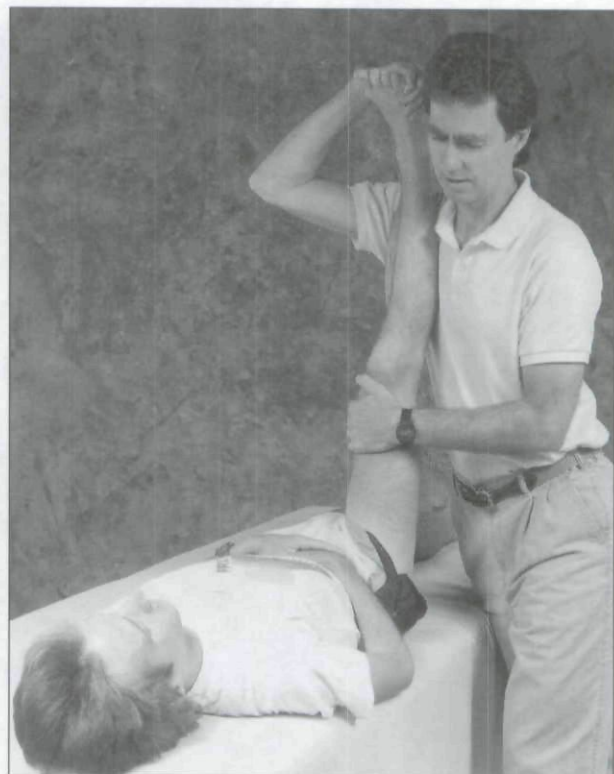
**a****b**

Figure 9 (a) Starting position of the PNF contract-relax hamstring stretch. (b) The stretcher actively deepens the stretch.

Reprinted, with permission, from R.E. McAtee, 1993, *Facilitated stretching*. (Champaign, IL: Human Kinetics), 14-15.

important to perform PNF relaxation techniques rapidly to achieve the desired inhibitory (relaxation) effect. Because the effect of the maximal depression lasts less than one second and 70 percent recovery occurs within five seconds, Moore and Kukulka (1991) suggest that "stretch increments should be applied immediately after the voluntary contraction, preferably within the first second and certainly by five seconds postcontraction."

Contract-Relax-Agonist-Contract (CRAC) Technique. The contract-relax-agonist-contraction technique is similar to the CR technique except that the relaxation phase is followed by an active contraction of the agonist (i.e., the antagonist of the tight muscle group, which in this instance are the quadriceps muscles). This last phase can also be assisted by the partner. Then the entire procedure is repeated.

The CRAC technique is based on the neurophysiology of reciprocal inhibition; that is, when the agonists (quadriceps) contract, the antagonists (hamstrings) relax. In addition, the CRAC method has been found to produce the greatest range of motion compared to other techniques (Moore and Hutton 1980). Another potential advantage is the facilitation of active flexibility. The major disadvantage of the CRAC technique is more discomfort and perceived pain.

Two frequently asked questions regarding the contraction phase of PNF exercises deal with its intensity and length of time. The originators of PNF and most early literature used the term *maximal* to describe the proper amount of resistance. However, many PNF instructors now consider the terms *optimal* or *appropriate* more accurate (Adler, Beckers, and Buck, 1993). This text uses *less than maximal* isometric contractions as recommended by McAtee (1993). The advantages include safety, less soreness, less tiring for the partner, and partners being able to work together despite differences in size and strength (McAtee 1993).

Length of time has been analyzed in a study comparing isometric contraction periods of zero, three, and six seconds. The research supported the hypothesis of the superiority of longer isometric contractions in active PNF groups; however, this superiority is absent from passive PNF groups (Hardy 1985). Further study of this complex issue is necessary.

PNF techniques offer a wider range of advantages and benefits than other conventional stretching methods. Most significant, PNF seems to be the most successful method for developing flexibility. The technique is also praised because it enhances active flexibility and helps establish a pattern for coordinated motion. It is also considered superior because it uses several important neurophysiological mechanisms, such as reciprocal innervation and the inverse myotatic reflex. PNF techniques are also thought to help reset the stretch reflex level or alter stretch perception (Magnusson et al. 1996). However, many of these assumptions have been challenged (Moore and Hutton 1980).

Unfortunately, PNF techniques have several disadvantages. Most important is the greater risk of injury, ranging from a pulled muscle to certain cardiovascular complications. Furthermore, the technique requires a knowledgeable and well-trained partner, which can be uneconomical in a practice session because one athlete (the partner) is neither stretching nor resting (Kurz 1994).

Stretching Aids

In addition to the techniques described above, there is another way to enhance range of motion by using specifically designed stretching machines. Stretching machines have been extensively promoted since the mid-1970s in a

variety of dance, gymnastics, martial arts, and yoga magazines. These machines vary in cost and sophistication. Dependent upon design and utilization, stretching machines can facilitate the development of either active, static, or passive flexibility. Perhaps the most popular and widely promoted device is the “rack” design (figure 10).



Figure 10 Universal Proflex stretching machine.

Note: The Universal Proflex is no longer available for purchase.

Photo furnished by Universal Gym Equipment, Inc., West Palm Beach, FL.

Consider a number of factors prior to purchasing any stretching device, including the safety, effectiveness, and durability of the product. Seek a knowledgeable certified athletic trainer, physical therapist, or physician to help evaluate a stretching device's safety and effectiveness. Ask the manufacturer if the device does what it claims or provides a free trial with a money-back guarantee. Also inquire how long the warranty lasts, what is necessary to get a temporary replacement, and how long it takes to get a replacement. Consider the materials and components that make up the machine. How sturdy is the device, and how will it stand up to wear and tear? Also consider the ease of operation or user friendliness of design. Does the machine require special training? Is it bulky, heavy, and large (making it difficult to store)?

WHAT CAUSES MUSCULAR SORENESS?

Athletes commonly experience discomfort, soreness, stiffness, or pain. These afflictions fall into two general categories: those that occur during and immediately

KNOWING A JOINT'S MAXIMUM SUSTAINABLE ACTIVE AND PASSIVE FLEXIBILITY

It is prudent to explain why coaches and athletes need to understand the importance of (1) developing both passive and active flexibility and (2) having quantified data on the limits of a joint's allowable active and passive range of motion. "By knowing the amount of reserve (the high rating of passive mobility) and the actual (passive and active) mobility in joints, one can determine the amount of potential increase" (Karmenov 1990). Calculate the potential increase of active flexibility by subtracting the measure of active flexibility from the measure of passive flexibility. This difference is the zone of active inadequacy. For example, given the amount of passive adequacy (flexibility) is 150 degrees, and the active adequacy (flexibility) is 100 degrees, then the potential increase in active flexibility is 50 degrees. Thus, the greater zone of active inadequacy, the greater is the potential to increase active flexibility. It is important to note, however, that there is also an increased likelihood of in-

jury with greater differences between the ranges of active and passive flexibility (Iashvili 1983).

Determine the potential increase in passive adequacy (flexibility) by subtracting the passive adequacy from the amount of reserve mobility, i.e., the high rating of passive mobility. This difference is the zone of passive inadequacy (see figure 8). For example, assume that elite acrobats or gymnasts should possess 180 degrees of hip flexion with the legs kept straight. (This high rating of passive mobility would be determined from standardized test data that establish set norms for related age groups.) If the zone of passive adequacy is 150 degrees, then the potential increase in passive adequacy is

$$180 \text{ degrees} - 150 \text{ degrees} = 30 \text{ degrees}$$

Such information can assist coaches and trainers in improving performance and reducing the risk of injury.

after the exercise (these may persist for several hours) and those that usually do not appear until 24 to 48 hours later. This muscle soreness can also occur as a result of stretching. Therefore, athletes and coaches need to understand what causes soreness to develop and implement strategies to eliminate or minimize its occurrence. Currently, there are four basic hypotheses that attempt to explain the nature of muscular soreness. Although these will be discussed separately, they can occur together. There also may be other causes of muscular soreness.

Torn or Damaged Tissue

This hypothesis states that soreness results from the microscopic tearing of muscle fibers or connective tissues (figure 11, *a* and *b*). More recently, this has been expanded into the connective tissue damage hypothesis, which suggests that the soreness is due to irritation or damage of connective tissue—usually a result of exercises or training that use eccentric contractions (for instance, the elongation or stretching of a muscle while it is contracting under resistance). Plyometrics is an example of a training technique that uses eccentric contractions.

Metabolic Accumulation, Pressure, and Swelling

This hypothesis emphasizes the accumulation of muscle metabolic by-products, leading to retained excess water (edema). In turn, the pressure on the athlete's sensory nerves creates the pain. An analogy is to compare muscle with a water balloon stuffed inside a nylon stocking. The increased volume of fluid produces passive tension throughout the stocking, resulting in pain, swelling, and stiffness. Although several researchers believe this theory is questionable, if not unlikely, it has yet to be disproved.

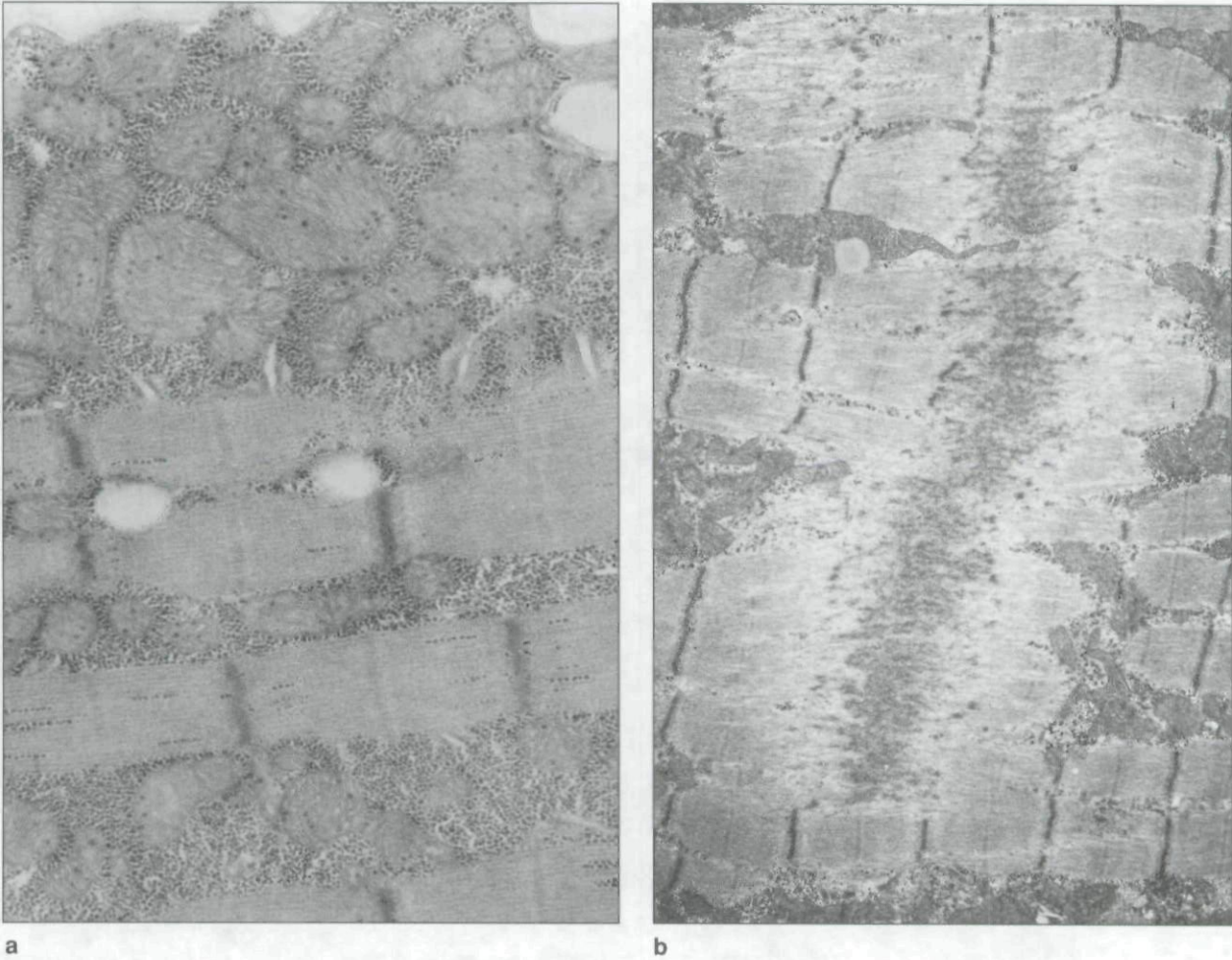


Figure 11 (a) An electron micrograph showing normal arrangement of the actin and myosin filaments and Z-disk configuration in the muscle of a runner before a marathon. (b) A muscle sample taken immediately after a marathon race shows a damaged sarcomere.

Reprinted, with permission, from J.H. Wilmore and D.L. Costill, 1994, *Physiology of sport*. (Champaign, IL: Human Kinetics), 79.

Lactic Acid Hypothesis

Lactic acid is a waste by-product of metabolism and can only form in the absence of oxygen. Therefore, lactic acid accumulates only when there is insufficient blood supply to the muscles. Consequently, lactic acid must not be a factor in pain following passive exercise and most static stretching programs.

Muscle Spasms

The localized spasm of motor units hypothesis developed by de Vries (1961, 1966) is intended to explain delayed localized soreness. By this hypothesis, exercise above a minimal level causes decreased blood flow to the muscle, or ischemia, which in turn causes pain that results in a protective reflex tonic muscle contraction. The tonic contraction brings about more ischemia, and a vicious cycle is born. Here, too, researchers have been unable to substantiate the findings of de Vries. Localized spasms may indeed be a source of localized

pain; however, the proposal that the initial cause is due to decreased blood flow to the muscle should not be a factor in pain following passive and static stretching exercises incorporated in athletic programs.

Some degree of soreness is often experienced by those who have not previously exercised or stretched—this is the penalty for having been inactive. The best ways to minimize the risk of soreness associated with stretching are as follows:

1. Precede stretching with a sufficient warm-up period.
2. Implement a progressive velocity flexibility program.
3. Use correct technique.
4. Do not neglect to develop other major components of fitness: agility, balance, endurance, strength, power, and speed.

Nonetheless, even well-trained athletes who work out at higher than usual levels of difficulty can also become sore or injured.

APPROPRIATE INJURY MANAGEMENT

If muscle soreness or an injury occurs, determine to the best of your knowledge the extent of the damage. As a general rule, rest, apply ice and pressure, and elevate the injured part of the body, then seek appropriate medical care. The sooner an injury is treated, the earlier rehabilitation can begin and the faster recovery will be.

HOW AGING AFFECTS FLEXIBILITY

Flexibility can be developed at any age, given the appropriate training; however, the rate of development may not be the same at every age for all athletes. Generally, research indicates that small children are quite supple, and that during the school years flexibility decreases until about puberty, then increases throughout adolescence. After adolescence, however, flexibility tends to level off and then decrease. Although flexibility decreases with age, the loss appears to be minimized in those who remain active. Research has found that maturational age as measured by sexual maturity, rather than by chronological age, was better correlated with strength and flexibility in the lower extremity. However, many parents, coaches, and adolescent athletes fail "to consider developmental variation [which] often leads to inappropriate performance expectations and an unsatisfactory sports experience" (Pratt 1989).

A primary factor responsible for flexibility decreasing with age is certain changes in the con-

nective tissues of the body. Interestingly, it has been suggested that exercise delays the loss of flexibility due to dehydration within the connective tissues. This is based on the notion that stretching stimulates the production or retention of lubricants between the connective tissue fibers, thus preventing adhesions. Other physical changes that occur with aging and affect flexibility include

- increased calcium deposits,
- increased dehydration in connective tissues,
- increased adhesions and cross-links in the connective tissues,
- an actual change in the chemical structure of the tissues, and
- the replacement of muscle fibers with fatty and fibrous (collagen) fibers.

ADDING A STRETCHING PROGRAM TO YOUR WORKOUT

A flexibility training program is a planned, deliberate, and regular program of exercises that can permanently and progressively increase the usable range of motion of a joint or set of joints over time (Aten and Knight 1978). In the arena of athletics, training in general is a multisided process to influence the development of an athlete and ensure the necessary level of preparation. Stretching exercises comprise just one essential component of an athlete's total training program.

Warming Up

A warm-up consisting of exercises performed immediately before an activity to increase circulation and heart rate is an essential part of a good conditioning program. Warm-up exercises provide an athlete with time to adjust from rest to exercise. These exercises are designed to improve performance and reduce the chance of injury by preparing the athlete mentally as well as physically for his or her sport. Physiologically, a warm-up elevates body temperature and increases blood flow.

Stretching is often incorrectly considered synonymous with warm-up because it is commonly done during the warm-up portion of a training program. In addition, static and passive stretching exercises do virtually nothing to increase core or peripheral temperatures and blood flow; hence, these stretching techniques do not serve as a warm-up. In fact, stretching should always be preceded by a warm-up because the elevated tissue temperature enhances connective tissue and muscular extension, thereby reducing the risk of injury from stretching.

Warm-up routines are typically classified into three categories. A passive warm-up involves raising the body temperature by some external means such as heating pads and hot showers. A general warm-up is probably the most commonly used technique. It employs various movements not directly related to those employed in the activity itself. These include joint rotations and gentle twisting and bending movements. This is usually followed by light calisthenics, brisk walking, jogging, or jumping rope. Here the goal is to increase muscle blood flow and raise core body temperature. A formal or specific warm-up includes movements that either mimic or are employed in the actual activity, performed at a reduced level of intensity.

The intensity and duration of a warm-up must be suited to the athlete's physical capabilities and adjusted to the existing conditions. Generally, an athlete's warm-up should be intense enough to increase body temperature and cause some sweating but not so intense as to cause fatigue. A warm-up should be more intense in cold weather.

BENEFITS OF A GOOD WARM-UP

- Increase in body and tissue temperature
- Increase of blood flow through the active muscles
- Increase in heart rate, which prepares the cardiovascular system for work
- Increase in the rate of energy release in the body (the metabolic rate)
- Increase in the exchange of oxygen from hemoglobin
- Increase in speed at which nerve impulses travel, facilitating body movements
- Increase in reciprocal innervation efficiency (allowing muscles to contract and relax faster and more efficiently)
- Decrease in muscular tension
- Enhanced ability of connective tissue to elongate
- Help in preparing the athlete psychologically

Duration, Frequency, Timing, and Intensity

There is much debate and little consensus about recommendations for duration, frequency, timing, and intensity of flexibility training (Alter 1996). Consider several important factors when designing a flexibility training program. Perhaps most important, the athlete or coach must identify the purpose of the flexibility training session. Specifically, is the purpose of the program development, maintenance, or rehabilitation of flexibility?

Ideally, a training program should be individually tailored to meet the needs of the athlete; however, many athletes train in a group or team flexibility program. This team-centered program is advantageous because it guarantees at least a minimal amount of stretching and fosters camaraderie and team spirit. However, in such cases, it is still essential that each individual athlete be properly instructed to concentrate on specific areas that need additional stretching on the athlete's own time. Let's briefly review what is commonly recommended for most healthy individuals.

Most programs recommend holding each stretch for 6 to 30 seconds. The problem with holding stretches for longer than 30 seconds is that warm-up and stretching programs in combination might last longer than many workouts. Furthermore, one study found that 30 seconds of static stretching of the hamstring muscles was as effective as the longer duration of 1 minute (Bandy and Irion 1994). This text recommends two to three repetitions of each stretch held for 10 seconds or one repetition of each stretch held for 20 to 30 seconds. The reasoning is simple: Lack of flexibility is primarily due to connective tissue whose permanent or plastic deformation is most favored by low-force, long-duration stretching (Sapega et al. 1981). If there is not enough time to optimally stretch during regular workout sessions, athletes must plan to stretch on their own time.

In fact, empirical evidence would probably reveal that the most significant contributing factor to dancer, gymnast, or martial artist improving his or her flexibility takes place when the individual stretches during his or her own time! Furthermore, it is tempting to speculate that as a consequence there is an increase in the passive flexibility reserve. In turn, this increased passive flexibility reserve increases one's potential for active flexibility. Consequently, it may be that passive or static flexibility is developed primarily on one's own, at home, whereas active or functional flexibility is developed in the dance studio, gym, or dojo where the passive flexibility is transformed into finely coordinated and skilled movement. Serious athletes must develop both their passive flexibility and active flexibility.

As training progresses, increase the number of successive repetitions for each routine. In addition, incorporate dynamic stretching performed in series, with a gradual increase in range of motion. The number of repetitions in series usually ranges from 8 to 12, but well-trained athletes may perform as many as 40 or more repetitions with maximum amplitude (Matveyev 1981). Some experts recommend three to six sets of 10 to 15 repetitions (Costill, Maglischo, and Richardson 1992). Keep in mind that fatigue and the consequent reduction in amplitude is a sign to stop (Harre 1982). If your muscles begin to quiver and vibrate, pain persists, or range of motion decreases, you have stretched too much. As a general rule, nonathletes should stretch at least

once a day, three to five days per week, to maintain flexibility. Depending on their sport, dedicated and serious athletes may require two to three stretching sessions per day for six or seven days per week.

When within a workout session should stretching exercises be done? Research refutes that specific placement of stretching exercises within a workout session makes a difference in increasing range of motion (Cornelius, Hagemann, and Jackson 1988). However, Sapega et al. (1981) recommend incorporating stretching immediately after the main part of a workout and cool-down period because tissue temperatures are highest, making stretching both safer and more productive.

Another question then arises: How intense should a stretch be to develop flexibility? Because intensity is based on subjective factors (tension, discomfort, pain), there is no way for coaches or trainers to determine this level for their athletes; the intensity of the stretch must be up to the athlete. In general, stretch to the point of tension but not pain. For athletes who are undergoing rehabilitation and have healing tissues, the point before pain is reached may be sufficient to rupture already weakened tissues. Remember, the best advice is to use common sense: Train, don't strain.

Improving and retaining flexibility depend on numerous variables, including genetic factors, age, and the state of training. Thus, your muscles' responses to regular stretching are a function of these factors and are dependent on which muscle group you stretch. Generally, for healthy individuals, the longer, more frequently, and more intensely you stretch, the faster and more significant your improvement in flexibility will be. If you are healthy, uninjured, and just starting a stretching program, you may feel increased muscle tightness and some muscle soreness the first week. But as your body adapts to regular stretching, you'll begin to see increases in your flexibility. Likewise, once you stop your stretching program, the flexibility gains will be lost over time.

Cooling Down

Cooling down is defined as performing a group of light exercises immediately after an activity to provide the body with a period of adjustment from exercise to rest. The cool-down period is valuable for athletes who want to maintain or enhance their flexibility. As tissue temperatures rise, stiffness decreases and extensibility increases. Because tissue temperatures will be highest immediately after a workout and during the cool-down phase, stretching is thought to be both safer and more productive.

Strength Training and Flexibility

Strength training is a vital component for athletes, although misconceptions exist regarding the relationship between strength training and flexibility (Todd 1985). Research demonstrates that weight training does not decrease flexibility and in some instances actually improves it (Wilmore et al. 1978). With proper training that is technically correct, an athlete can improve both overall strength and flexibility.

A common belief is that strength training significantly increases range of motion if: (1) stretching exercises are included in the training program, (2) both the agonist and antagonist muscle groups are trained, (3) the entire muscle

or muscle group is worked through its full range of motion, and (4) there is a gradual emphasis on accentuating the negative phase of work. Negative work or eccentric contractions take place when a muscle is stretched (elongated) while it is contracting. This eccentric contraction is associated with the lowering phase of a resistance exercise. Unfortunately, eccentric training is also associated with a greater risk of muscle soreness.

THE CONTROVERSY ABOUT STRETCHING

Although stretching exercises are thought to prevent injury and improve performance in a number of sports, stretching exercises should *not* be considered a panacea. For some athletes, excessive flexibility may destabilize joints and may actually *increase* the likelihood of ligament injury and joint separation or dislocation. Another argument is that stretching may lead to joint hypermobility. Hypermobility is said to be present when the joints are unduly lax and the range of motion is in excess of the accepted norm in most of the joints. In turn, hypermobility may be a factor in decreased positional sense (proprioceptive acuity), which may increase the risk of acute or chronic injury. Some experts also feel that excessively loose joints may lead to premature development of osteoarthritis in athletes.

What, then, are the precautions for stretching, and when is it considered inadvisable? The most commonly cited precautions are listed below.

Don't stretch an area in question if

- a bone blocks motion;
- you recently fractured a bone;
- you suspect or know of an acute inflammatory or infectious process in or around a joint;
- you have osteoporosis;
- you experience sharp, acute pain with joint movement or muscle elongation;
- you've had a recent sprain or strain;
- your joint lacks stability;
- you suffer from certain vascular or skin diseases; or
- you experience a loss of function or decrease in range of motion.

These precautions are matters of professional medical opinion, not established fact. If you have doubts or questions about whether a stretch is right for you, consult a qualified physical therapist, athletic trainer, or medical professional.

ADVANCED STRETCHES

Virtually every stretch presents some risk. The possibility of an injury depends on numerous variables, including an athlete's state of training, age, previous injuries, structural abnormalities, fatigue, and technique. So should you incorporate advanced or "controversial" stretches into your program? According to Harold B. Falls, PhD, professor of biomedical science at Southwest Missouri State University and an editorial board member of *The Physician and Sportsmedicine*: "Everything depends on the individual. There are some exercises some people can't do, and there are others that some people can do" (Lubell 1989). Mel Siff (1993b), PhD and editor of *The International Fitness Scientist* (South Africa) agrees: "There is generally no such thing as an unsafe stretch or exercise: only an unsafe way of executing any movement for a specific individual at a specific time" (p. 128).

The stretches listed below are rated "advanced." By this rating, I mean they may be too advanced or dangerous for inactive and moderately active individuals and even for some serious or elite athletes as well. These stretches are highlighted here because, although they may not be safe for everyone, they are considered essential for dance, diving, figure skating, gymnastics, martial arts, wrestling, and yoga. In these disciplines, certain advanced stretches cannot be avoided. But if you incorporate these exercises into your training program, take the appropriate preventive measures to reduce risk of injury. In general, perform these stretches as you would any other stretch in this book: slowly, deliberately, and precisely.

The Plough

The plough (stretch 236) places excessive strain on the lower back and disks and is potentially dangerous for those with low back problems. This stretch can also create a strong stretching force on the neck. Another problem with the plough is that it stretches a region frequently flexed from faulty posture and the exercise reinforces the faulty posture. Last, it compresses the lungs and heart and interferes with breathing if there is an excessive deposit of fat around the abdominal region. However, the plough is essential for those involved in judo, wrestling, some martial arts, and yoga. The easiest way to reduce the risk of injury is to learn the exercise correctly in sequential stages.

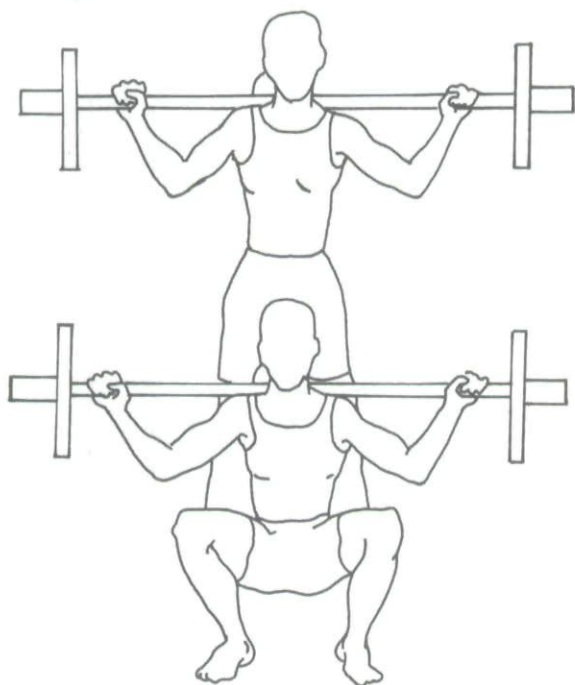


Traditional Hurdler's Stretch



The traditional hurdler's stretch is designed to stretch the hamstrings along with the lower back muscles and related soft tissues. It also stretches the medial ligaments of the knee. For some individuals, this stretch promotes knee instability and twists and compresses the kneecap, which can cause the kneecap to side-slip. This stretch is commonly recommended for improving performance and preventing or rehabilitating injuries. The easiest way to reduce the risk of injury is to have the flexed leg positioned so that the outer side of the thigh and calf can rest on the floor, with the heel against the inner side of the opposite thigh.

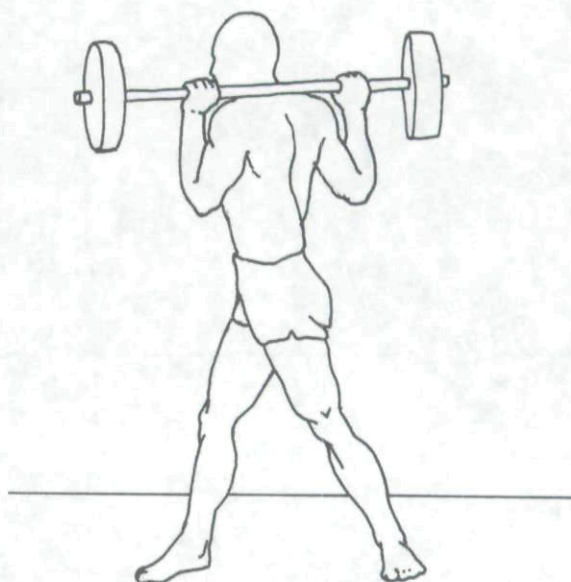
Deep Knee Bend



The deep knee bend (stretch 40), lunge, or squat (with or without weights) can endanger the lateral ligaments of the knee, compress the kneecap, and pinch and damage the cartilage in the knee. This stretch is a basic component of numerous skills in baseball, dance, gymnastics, handball, weight lifting, and wrestling. Minimize the degree of risk by reducing the velocity and depth of the descent and maintaining the knees over the long axis of the foot.

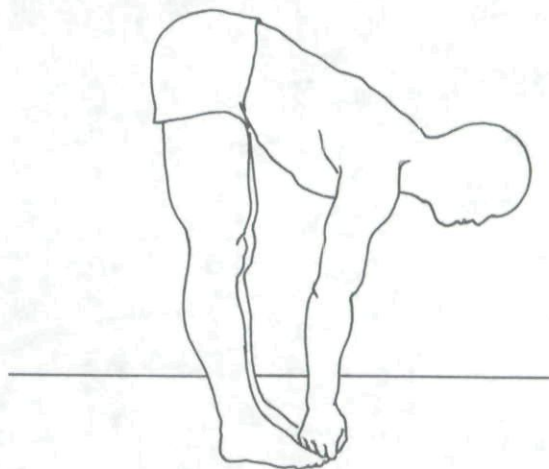
Standing Torso Twist

The standing torso twist (with or without weights; stretch 225) can strain the ligaments of the knee and incorporate momentum that often exceeds the absorbing capacity of the tissues being stretched. This exercise is used in many disciplines, including baseball, discus, golf, tennis, and the javelin throw. Risk-reduction strategies include placing the hands on the hips, sitting in a chair, or slightly flexing the knees when standing.

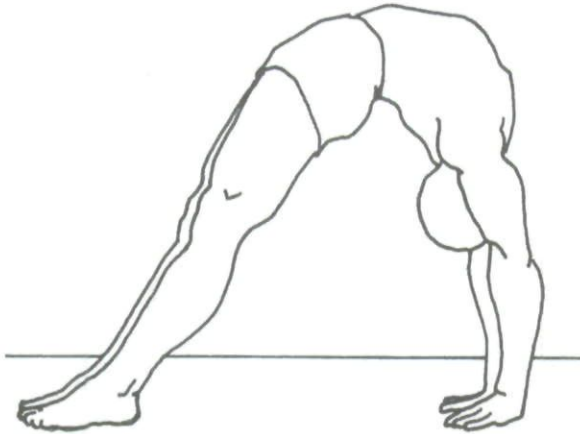


Straight-Leg Stand and Toe Touch

The straight-leg stand and toe touch (straddle or nonstraddle; stretch 75) stresses the medial aspect of the knees, forces the knee to hyperextend, places greater pressure on the lumbar spine, and can result in permanent deformity, both as loose and knock-knees. This exercise is essential in several sports and disciplines such as 3- and 10-meter diving, gymnastics, power lifting, weight lifting, and yoga. Minimize the risk of injury by avoiding ballistic movements or initiating the stretch from a squatting position.

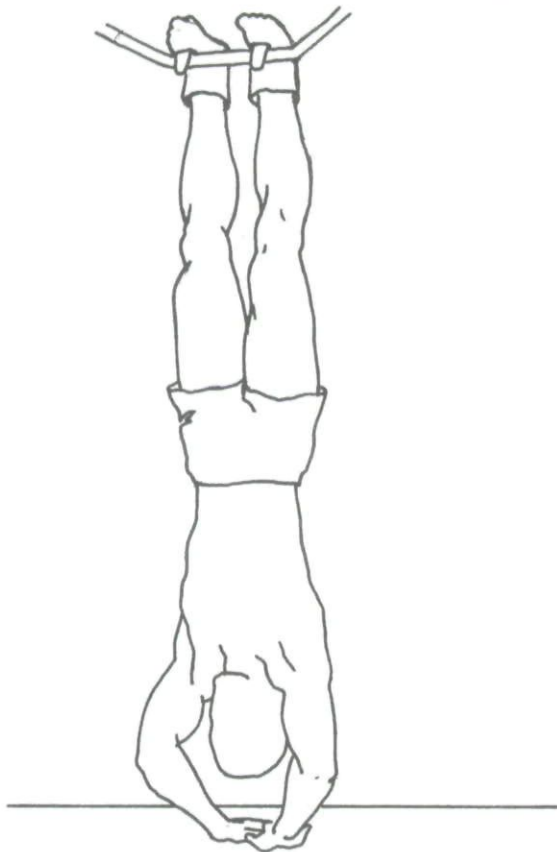


Bridge



The bridge (stretch 187) squeezes the spinal disks and pinches the nerve fibers. In addition, there is concern that repetitive bridging can cause spondylolysis or low back pain. The rationale for incorporating a bridge in a training program is that it is a required skill in many disciplines such as acrobatics, gymnastics, judo, and wrestling. Risk-reduction strategies include proper sequential learning through lead-up drills and exercises, using optimal technique, and the assistance of a knowledgeable spotter.

Inversion



Inversion (stretch 206) raises blood pressure, may rupture blood vessels—especially in the eyes, and may injure those with spinal instability. Inversion exercises have been hypothesized to relieve or prevent low back pain, hence they are used in rehabilitation.

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