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An Update on Flexibility

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summary

Most medical professionals, coaches, and athletes consider flexibility training an integral component of any conditioning program. Definitive research will assist in dispelling common misconceptions often associated with flexibility training. The purpose of this article is to provide an update on the latest research regarding flexibility training.

Most medical professionals, coaches, and athletes consider aerobic conditioning, strength training, and flexibility to be integral components in any conditioning program (7, 10, 19, 20, 25, 31). Some of the proposed benefits of enhanced flexibility are reduced risk of injury (7, 10, 19, 20, 25, 31), pain relief (20), and improved athletic performance (3, 50). A lack of definitive research makes it difficult to make recommendations regarding an effective flexibility program.

The purpose of this article is to provide an update on the latest research regarding flexibility training. Definitive research will assist in dispelling common misconceptions often associated with flexibility training.

Full range of motion across a joint is dependent on 2 components: joint range of motion and muscle length (52). Joint range of motion is the motion available at a single joint and is influenced by bony structures, ligaments, and the capsule. Muscle length and flexibility are used interchangeably to describe the ability of a muscle to lengthen to allow 1 joint (or more than 1 joint in a series) to move through a range of motion (ROM). Loss of flexibility is defined as a decrease in the ability of a muscle to deform (52).

Other authors have defined flexibility in a similar fashion. Anderson and Burke (3) defined flexibility as the range of motion of a joint or series of joints that are influenced by muscles, tendons, ligaments, bones, and bony structures. DeVries (14) suggested that flexibility is the measured range of motion available about a joint or series of joints.

Types of Stretching

Ballistic Stretching

Ballistic stretching is a technique involving a rhythmic bouncing motion. The muscle to be stretched is held stationary while the nonstationary lever is rhythmically bounced. The bouncing utilizes the momentum of the extremity to lengthen the muscle (3). Significant increases in ROM have been documented through the use of ballistic stretching, but many argue that the rigorous energy used in this technique places the subject at an increased risk of muscle injury (20, 25, 31, 46, 49). Also, the use of high tension over a short period of time does not correlate with the use of low force over an extended period of time, which has been found to be most effective for stretching a muscle (43).

An argument can be made that many sporting activities involve high-tension or intensity, short-duration eccentric contractions and that to properly prepare an athlete for these events a degree of limited ballistic activity is necessary. The sporting activity may place the athlete at a much higher risk than would a controlled ballistic stretching program. A study by Vujnovich and Dawson (48) found that by following a static stretch with a ballistic stretch, they were able to significantly decrease the activity of motor neurons within the L5–S1 spinal segment. These reported results indicate that static stretching alone provides this inhibition as well, but not to the extent that static stretching followed by a ballistic stretch does. Eccles et al (16) suggested that the inhibition of the motor neuron during ballistic stretching but not during static stretching is due to the Golgi tendon organ. The Golgi tendon organ is insensitive to slow velocity length changes of muscle in intact preparations (11, 21, 22) but provides a dynamic response during rapid stretching (2, 17, 22, 26).

Contrary to the decrease in motor neuron activity reported by Vujnovich and Dawson (48), Guissard et al (18) reported that ballistic stretching caused the facilitation of the stretch reflex, which is mediated by the facilitatory influences of muscle spindle type Ia and II receptors upon homonymous alpha motor neuron excitability. This activation of the stretch reflex causes a contraction in the muscle being stretched. Therefore, as the individual bounces, the muscle responds by contracting to protect itself from overstretching. Also, eliciting the myostatic stretch reflex increases the magnitude and rate of the stretch, which can, theoretically, strain or rupture the muscle. Irrespective of the influence on the motor neurons reported in the literature, the typical flexibility program does not incorporate ballistic stretching (52).

Proprioceptive Neuromuscular Facilitation

Proprioceptive neuromuscular facilitation (PNF) was introduced in 1968 by Knott and Voss (28), who defined the method as a way of "promoting or hastening the neuromuscular mechanism through stimulation of the proprioceptors." PNF has been used to increase strength and flexibility and to enhance coordination. Specific to increasing flexibility of muscle, PNF techniques involve the use of brief isometric contractions of the muscle to be stretched prior to statically stretching the muscle. These techniques facilitate the Golgi tendon organ in the muscle performing the isometric contraction, causing autogenic inhibition in that muscle and allowing elongation. In the technique referred to as contract relax, the subject performs an isotonic contraction while another person trained in PNF resists the motion. The subject performing the contraction is then instructed to relax. The assistant then moves the extremity passively through as much range as possible, to the point where limitation is again felt to occur.

Sady et al (41) compared the effects of stretching techniques on the flexibility of the trunk, shoulders, and hamstrings in 43 college-aged men. Baseline measures were obtained, and then the subjects began a 6-week program using static stretching, ballistic stretching, or PNF. The measurements following the 6 weeks of stretching revealed that the subjects performing the PNF technique had the most improved range of motion in all 3 areas stretched.

A limitation with the use of PNF is that PNF requires 1-on-1 intervention with an experienced individual (28, 39). Other stretching can easily be performed without any outside intervention.

Static Stretch

Static stretching is elongating a muscle to tolerance and sustaining the position for a length of time (3, 30). According to Smith (45), static stretching has the least associated injury risk and is believed to be the safest technique compared with other stretching techniques. Numerous authors have stressed the importance of static stretching as a part of training for athletics and sports medicine (1, 12, 29, 37, 42, 44) and have indicated that static stretching is the most common method of stretching used to increase the flexibility of the muscle (41, 52). Static stretching is the most commonly used form of flexibility training because it carries the lowest risk of injury, does not require 1-on-1 intervention with an experienced individual, and is effective for improving flexibility.

Bandy and Irion (6) performed a study in which subjects stretched for 0, 15, 30, and 60 seconds 5 days a week for 6 weeks. The study found that 30 and 60 seconds of stretching were each more effective at increasing flexibility than stretching for 15 seconds or not stretching at all. No significant difference occurred between those stretching for 30 and 60 seconds, indicating that 30 seconds of stretching was as effective as 1 minute.

Bandy et al (7) also examined the effects of time and frequency of static stretching on flexibility. A total of 93 subjects were assigned to 1 of 5 groups. The 4 stretching groups stretched 5 days a week for 6 weeks. Group 1 performed 3 1-minute static stretches of the hamstring muscles with a 10-second rest in between. Group 2 performed 3 30-second static stretches with a 10-second rest in between. Group 3 performed 1 static stretch for 1 minute. Group 4 performed 1 static stretch for 30 seconds, and group 5 served as a control. The results of this study suggest that 1 30-second duration static stretch is an effective method of stretching the hamstring muscle in order to increase range of motion. No further increased range resulted from either increased frequency or duration (7).

Dynamic Range of Motion

Dynamic range of motion (DROM) is a relatively new method used to lengthen a muscle. The method is described by Murphy (34, 35) as a technique that allows the muscle being lengthened to elongate naturally and in its relaxed state. This elongation is achieved by contracting the antagonist muscle and moving the joint the muscle crosses through the full available range in a slow and controlled manner. For example, if the subject was stretching the hamstring muscles dynamically, he or she would contract the quadriceps muscles and extend the knee. The extension to the end range of motion would cause the hamstring to elongate. The firing of the antagonistic muscle (in this example, the quadriceps) will cause the agonist hamstrings to relax through reciprocal inhibition (38).

Murphy (35) provided several arguments for using DROM instead of a passive type of stretching activity. First, DROM can increase the temperature within the working muscle (33). Studies have shown that a warmed muscle produced faster and more forceful contractions (33), improved muscular work (33,42), and increased speed of the transmission of the nerve impulses (42). Second, Murphy (35) argued that dynamically stretching a muscle after exercise will increase blood flow to the region, thus removing lactic acid and possibly reducing delayed onset muscle soreness (described later in the literature review). The properties of static stretching may not afford this capability because of the passive nature of static stretching. Third, Murphy (35) went on to suggest that while static stretching is the most popular technique for improving flexibility, it has not been proven to improve athletic performance.

Hubley et al (23) performed a study on 30 subjects between 14 and 60 years of age to compare the effects of 15 minutes of static stretching and 15 minutes of stationary cycling on flexibility for both hip flexion and extension. Measurements were taken following a full explanation of the experimental procedure, immediately after the static stretching or cycling, and 15 minutes later. The authors found no difference in gains in hip flexion and hip extension between the 2 groups measured immediately or 15 minutes after the activity. The authors concluded that both stretching and cycling were found to be equally beneficial exercises for "increasing (immediate post measure) and maintaining (15 minute post measure)" the increase in flexibility.

Conversely, Bandy et al (8) compared DROM to static stretching to improve flexibility in the hamstrings. Fifty-eight subjects participated in the study. One group performed DROM 5 days a week by lying supine with the hip held in 90 degrees of flexion. The subject then actively moved the leg into extension and held the leg in the end range for 5 seconds, then slowly lowered the leg. The movements were performed 6 times per session. The second group performed 1 30-second static stretch 5 days a week. The third group served as a control. The authors found that although both static stretch and DROM increase hamstring flexibility, a 30-second static stretch was more effective than DROM for enhancing flexibility. The gains made by those who statically stretched were more than double the gains made by those subjects who stretched dynamically.

Eccentric Flexibility Training

Recently, eccentric training through a full range of motion has been introduced in the literature as a method to increase hamstring flexibility (36). To perform eccentric training through a full range of motion, each subject laid supine with the leg that was not being stretched straight. In each hand the subject held an end of a 3-foot piece of black resistance band, with the leg to be stretched locked in full extension and the hip in neutral. The subject was instructed to bring the hip to be stretched into full hip flexion by pulling with both arms on the resistance band attached to the foot, making sure the knee remained locked in full extension at all times. Full hip flexion was defined as the position of hip flexion at which a gentle stretch was felt by the subject. As the subject pulled the hip into full flexion, the subject was instructed to simultaneously resist the hip flexion by eccentrically contracting the hamstring muscles. The extremity was then brought back into hip extension.

Nelson and Bandy (36) investigated the effectiveness of eccentric training through the full range of motion by comparing 3 types of stretching activities in high school-aged males. The first group performed a 30-second static stretch 4 times a week over a 6-week period of time. The second group eccentrically trained the hamstring muscle through a full range of motion 4 times a week for 6 weeks. The third group performed no flexibility training and served as the control group. At the end of the study, the control group had gained an average of 1.17° of motion over the 6-week period, while the static stretch and eccentric training groups gained 12.04° and 12.79° respectively. Posttest measures indicated no significant differences between the static stretch and eccentric training groups, but there was a significant difference between the groups performing flexibility training and the control group. The authors felt that if you combine the benefits of an eccentric training program (strength gains, possible reduction of injury rates, and specificity of training) with range of motion gains equal to that of static stretching, compelling evidence exists to incorporate eccentric training into an exercise program.

Proposed Benefits of Stretching

As indicated in the previous section, a variety of types of stretching techniques exist for increasing flexibility. The reason that so much time and energy has been allotted to researching the appropriate stretching technique is that it has been suggested that an effective stretching program can warm the muscles, decrease pain, increase stretch tolerance, assist in returning the body to a more steady state, reduce the risk of injury, and improve athletic performance (34). Previous research examining each of these claims will now be examined.

Increase Temperature of the Muscle

As muscle temperature rises, the metabolic processes increase and viscosity throughout the muscle decreases (29). An increase in the metabolic rate and a decrease in viscosity lead to a smoother contraction of the muscle and an increase in oxygen uptake; changes which result in improved muscle function. Research has found that higher muscle temperatures also speed up the transmission of nerve impulses (42), which may produce faster and more forceful contractions (33). Blood traveling through a warmed muscle also increases in temperature. As blood temperature rises, oxygen more readily dissociates from hemoglobin and thus is delivered to the tissues more efficiently. This change makes more oxygen available to working muscles (4).

Murphy (34) argued that a typical flexibility program consisting of only static stretching does nothing to warm the muscles, and the heating benefit to the muscle is not achieved. If a muscle is statically stretched, no warming effect occurs. A more appropriate procedure for warming is through active contractions, which is why Murphy (34) suggested that active or dynamic range of motion activities were better to utilize in preparing a muscle for activity.

Effect on Injury Rates

The reason most often given for incorporating a stretching program into any athletic endeavor is to reduce the chances of injury. Although several authors suggest that stretching will reduce injuries (7, 10, 19, 20, 25, 31), empirical evidence is lacking. Levine et al (32) sampled stretching programs of intercollegiate athletes to determine tendencies in stretching practices. The study found that the hamstrings were among the muscle groups stretched by most athletes (92%). The study also stated that hamstring strains were one of the most reported injuries. Cross and Worrell (13) incorporated a flexibility program for a football team and reported a decrease in the number of lower extremity injuries. However, no data was provided indicating whether or not the players made gains in the amount of flexibility after incorporating this program. The authors concluded that they believed many factors were involved in the reduction in the number of injuries.

Jonhagen et al (27) compared 11 sprinters with a history of a previous hamstring injury with 9 uninjured runners. Measurements compared in each group were flexibility, concentric torque, and eccentric torque of the quadriceps and hamstring muscles at different velocities. The authors found that the sprinters with a history of a previous injury had significantly tighter hamstrings than the uninjured sprinters. The uninjured sprinters had significantly higher eccentric hamstring torques at all velocities and had significantly higher torques concentrically in the quadriceps and hamstrings when tested at 30° per second. The authors concluded that the sprinters with a history of hamstring injury differed from their counterparts in that they were weaker at all speeds eccentrically and at low speeds concentrically, and they also were significantly less flexible.

Contrary to popular public opinion, several authors have found that stretching does not reduce the risk of injury (1, 24, 40, 43, 47, 49). Hubley-Kozey and Stanish (24) performed a literature review and, although the authors concluded that a stretching program should become an integral part of an athlete's training regime, they also stated that no proof exists that stretching (static, ballistic, or PNF) can reduce the risk of injury. In a review of the literature, Agre (1) reported that the most commonly cited cause of hamstring strains was weakness in the hamstring muscles. But, in the studies cited, the author did not find a significant relationship between hamstring flexibility and hamstring strain injuries. Van Mechelen et al (47) found that, while a health education intervention was effective in improving specific knowledge of warm-up and cool-down techniques, the intervention was not effective in reducing the number of running injuries.

Shrier (43) reviewed 5 studies and gave several reasons as to why stretching before exercise would not prevent injuries. First, stretching before exercise should have no effect for activities in which excessive muscle length is not an issue. Activities such as long distance running and cycling do not require a great deal of range of motion. If the activity performed does not require a great deal of hamstring flexibility, it is not necessary to spend a great deal of time stretching the hamstrings. Second, stretching will not affect muscle compliance during eccentric activities, when most strains are believed to occur. If most injuries occur during the eccentric phase of activity, the rate of injury would be more effectively reduced by being activity specific and performing eccentric activities. Third, stretching can produce damage at the cytoskeleton level. According to Shrier (43), the passive force placed on the muscle causes microtrauma in the muscle being stretched. Continued microtrauma to a muscle will weaken and predispose the muscle to injury. Fourth, stretching appears to mask pain in humans. The increase in stretch tolerance may mask the pain that is necessary for the muscle to react to prevent an injury.

A study by Worrell et al (49) examined athletes participating in high-risk sporting activities and compared noninjured athletes with athletes who had sustained a hamstring injury in the past 18 months. The athletes were tested isokinetically, and the flexibility of each athlete was measured. Isokinetically the strength values were similar for both groups. The researchers did find that those athletes with a history of a hamstring injury had a lack of flexibility compared with their uninjured counterparts. The authors stated that the lack of flexibility following a hamstring injury needed to be at the top of the priority list as far as rehabilitation is concerned (49).

The authors took this particular study a step further and included having each athlete fill out a questionnaire. One of the most interesting findings in the questionnaire was that 81% of the athletes with hamstring injuries had performed some type of hamstring stretching technique before they were injured.

Pope et al (40) performed a study on the effect of muscle stretching during warm-up on the risk of exercise related injuries. The authors followed 1,538 male Army recruits and concluded that a typical muscle-stretching protocol performed during pre-exercise warm ups did not produce clinically meaningful reductions in risk of exercise related injury in Army recruits.

Effect on Athletic Performance

Anderson and Burke (3) stated that optimal flexibility aids in athletic performance, but they do not support this claim with any evidence. Dintiman (15) performed a study related to sprint training by dividing athletes into 5 groups. The first group underwent sprint training combined with a static stretching program. A second group underwent a conventional sprint training program combined with a weight-training program. A third group combined sprint training, a weight-training program, and a static-stretching program. The fourth group underwent sprint training only, and the fifth group was a control. The training involved 145 subjects and lasted 8 weeks. The results indicated that no difference existed in improvement of running speed between the group that underwent sprint training combined with static stretching and the group that underwent sprint training alone. The groups incorporating a weight-training program as well as a flexibility program with the sprint training made significantly more improvements than the sprint-training program alone. The group supplementing the sprint training with a weight program did not improve significantly more than the group only performing sprint training.

The following studies have actually found a decrease in athletic performance as a result of static stretching. Avela et al (5) had 20 healthy male subjects participate in a study in which they underwent repeated passive stretching of the calf muscles. The authors found a clear deterioration of the muscle function following the stretching program, as indicated by a 23.2% decrease in torque. The authors suggested that these changes were associated with "a clear immediate reduction in the reflex sensitivity," resulting from the reduced sensitivity of the muscle spindles to repeated stretch.

Behm et al (9) measured isometric maximum voluntary contraction force of the quadriceps and hamstring muscles in 18 subjects. Six subjects were placed in a control group, and 12 subjects in the study group had the same measurements taken 5 to 10 minutes after a 20-minute bout of static stretching. The authors found that a significant decrement (12%) occurred in maximum voluntary contraction force after stretching in the 12 subjects performing the static stretching. No significant changes were found in the control group.

A study by Young and Behm (51) examined the effects of submaximal running, static stretching of the quadriceps and gluteal muscles, and practice jumps on vertical jump height. The authors found that 4 minutes of submaximal running and practice jumps provided significantly greater vertical jump height than static stretching. Young and Behm (51) concluded that "stretching produced a negative effect on performance and a more realistic athletic warm-up would be beneficial".

Conclusion

A lack of definitive research makes for difficulty in making recommendations regarding effective flexibility programs. As indicated in this literature review, the most commonly used form of flexibility training for increasing flexibility is static stretching, but questions exist as to whether static stretching can reduce injury rates and improve athletic performance. The search continues for an activity that will increase flexibility as well as static stretching does. If an activity is found that will accomplish this task, other avenues of research will be open to determine if gains are made in strength, injury reduction, and performance improvement.

Two activities of interest as an alternative to the static stretch for increasing flexibility of a muscle are PNF and eccentric training. One limitation of PNF training is the need for a trained person to assist with the activity. The assistance needed with PNF may cause that form of flexibility training to be used less often, even though the research proves it to be a very good alternative to static stretching. As indicated in the literature, training a muscle eccentrically has been reported to strengthen the muscle, as well as provide neuromuscular adaptations which may also reduce the chances of injury in the hamstring muscles. More research is needed to determine whether the eccentric range of motion activity can actually improve strength while improving flexibility. ♦

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