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CURRENT CONCEPTS IN MUSCLE STRETCHING FOR EXERCISE AND REHABILITATION

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Abstract

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Stretching is a common activity used by athletes, older adults, rehabilitation patients, and anyone participating in a fitness program. While the benefits of stretching are known, controversy remains about the best type of stretching for a particular goal or outcome. The purpose of this clinical commentary is to discuss the current concepts of muscle stretching interventions and summarize the evidence related to stretching as used in both exercise and rehabilitation.

Keywords: Exercise, fitness, rehabilitation, stretching

INTRODUCTION

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Human movement is dependent on the amount of range of motion (ROM) available in synovial joints. In general, ROM may be limited by 2 anatomical entities: joints and muscles. Joint restraints include joint geometry and congruency as well as the capsuloligamentous structures that surround the joint. Muscle provides both passive and active tension: passive muscle tension is dependent on structural properties of the muscle and surrounding fascia, while dynamic muscle contraction provides active tension ([Figure 1](#)). Structurally, muscle has viscoelastic properties that provide passive tension. Active tension results from the neuroreflexive properties of muscle, specifically peripheral motor neuron innervation (alpha motor neuron) and reflexive activation (gamma motor neuron).



[Figure 1.](#)

Factors contributing to muscle tension.

Obviously, there are many factors and reasons for reduced joint ROM only one of which is muscular tightness. Muscle “tightness” results from an increase in tension from active or passive mechanisms. Passively, muscles can become shortened through postural adaptation or scarring;

actively, muscles can become shorter due to spasm or contraction. Regardless of the cause, tightness limits range of motion and may create a muscle imbalance.

Clinicians must choose the appropriate intervention or technique to improve muscle tension based on the cause of the tightness. Stretching generally focuses on increasing the length of a musculotendinous unit, in essence increasing the distance between a muscle's origin and insertion. In terms of stretching, muscle tension is usually inversely related to length: decreased muscular tension is related to increased muscle length, while increased muscular tension is related to decreased muscle length. Inevitably, stretching of muscle applies tension to other structures such as the joint capsule and fascia, which are made up of different tissue than muscle with different biomechanical properties.

Three muscle stretching techniques are frequently described in the literature: Static, Dynamic, and Pre-Contraction stretches ([Figure 2](#)). The traditional and most common type is static stretching, where a specific position is held with the muscle on tension to a point of a stretching sensation and repeated. This can be performed passively by a partner, or actively by the subject ([Figure 3](#)).



[Figure 2.](#)

Techniques of Muscle Stretching. HR=Hold relax;
CR=Contract relax; CRAC= Contract relax, agonist contract;
PIR= Post-isometric relaxation; PFS=Post-facilitation
stretching, MET= Medical exercise therapy.



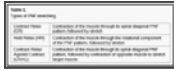
[Figure 3.](#)

Static stretching of the posterior shoulder (Used with permission of the Hygenic Corporation).

There are 2 types of dynamic stretching: active and ballistic stretching. Active stretching generally involves moving a limb through its full range of motion to the end ranges and repeating several times. Ballistic stretching includes rapid, alternating movements or 'bouncing' at end-range of motion; however, because of increased risk for injury, ballistic stretching is no longer recommended.¹

Pre-contraction stretching involves a contraction of the muscle being stretched or its antagonist before stretching. The most common type of pre-contraction stretching is proprioceptive neuromuscular facilitation (PNF) stretching. There are several different types of PNF stretching ([Table 1](#)) including "contract relax" (C-R), "hold relax" (H-R), and "contract-relax agonist contract" (CRAC); these are generally performed by having the patient or client contract the muscle being used during the technique at 75 to 100% of maximal contraction, holding for 10

seconds, and then relaxing. Resistance can be provided by a partner or with an elastic band or strap ([Figure 4](#)).



[Table 1.](#)

Types of PNF stretching.



[Figure 4.](#)

Contract-Relax stretching with stretching strap (Used with permission of the Hygenic Corporation).

Other types of pre-contraction stretching include “post-isometric relaxation” (PIR). This type of technique uses a much smaller amount of muscle contraction (25%) followed by a stretch. Post-facilitation stretch (PFS) is a technique developed by Dr. Vladimir Janda that involves a maximal contraction of the muscle at mid-range ([Figure 5](#)) with a rapid movement to maximal length followed by a 15-second static stretch.²



[Figure 5.](#)

Post-Facilitation Stretching of hamstrings (Used with permission of the Hygenic Corporation).

STRETCHING RESEARCH

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Many studies have evaluated various effects of different types and durations of stretching. Outcomes of these studies can be categorized as either acute or training effects. Acute effects measure the immediate results of stretching, while training effects are the results of stretching over a period of time. Stretching studies also vary by the different muscles or muscle groups that are being examined and the variety of populations studied, thereby making interpretation and recommendations somewhat difficult and relative. Each of these factors must therefore be considered when making conclusions based on research studies. Several systematic reviews of stretching are available to provide general recommendations.³⁻⁶

The effectiveness of stretching is usually reported as an increase in joint ROM (usually passive ROM); for example, knee or hip ROM is used to determine changes in hamstring length. Static stretching often results in increases in joint ROM. Interestingly, the increase in ROM may not be caused by increased length (decreased tension) of the muscle; rather, the subject may simply have an increased tolerance to stretching. Increases in muscle length are measured by “extensibility”, usually where a standardized load is placed on the limb and joint motion is measured. Increased tolerance to stretch is quantified by measuring the joint range of motion with a non-standardized load. This is an important question to consider when interpreting the results of studies: was the improvement based on actual muscle lengthening (ie, increased extensibility) or just an increase in tolerance to stretch?⁷ Chan and colleagues⁸ showed that 8 weeks of static stretching increased muscle extensibility; however, most static stretching training

studies show an increase in ROM due to an increase in stretch tolerance (ability to withstand more stretching force), not extensibility (increased muscle length).⁹⁻¹²

Static stretching is effective at increasing ROM. The greatest change in ROM with a static stretch occurs between 15 and 30 seconds;^{13,14} most authors suggest that 10 to 30 seconds is sufficient for increasing flexibility.¹⁴⁻¹⁷ In addition, no increase in muscle elongation occurs after 2 to 4 repetitions.¹⁸

Unfortunately, however, static stretching as part of a warm-up immediately prior to exercise has been shown detrimental to dynamometer-measured muscle strength¹⁹⁻²⁹ and performance in running and jumping.³⁰⁻³⁹ The loss of strength resulting from acute static stretching has been termed, “stretch-induced strength loss.”³ The specific causes for this type of stretch induced loss in strength is not clear; some suggest neural factors,^{31,40} while others suggest mechanical factors.^{19,23} Furthermore, the strength loss may be related to the length of the muscle at the time of testing²³ or the duration of the stretch.²⁵ Interestingly, a maximal contraction of the muscle being stretched before static stretching may decrease stretch-induced strength loss.⁴¹

Contraction of a muscle performed immediately before it is stretched is effective at increasing ROM. While most pre-contraction stretching is associated with PNF-type contract-relax or hold-relax techniques using 75 to 100% of a maximal contraction, Feland et al⁴² showed that submaximal contractions of 20 or 60% are just as effective, thus supporting the effectiveness of post-isometric relaxation stretching. Interestingly, ROM increases are seen bilaterally with pre-contraction stretching,⁴³ supporting a possible neurologic phenomenon.

The specific phenomenon associated with an increase in flexibility following a pre-stretch contraction remains unclear. Many have assumed that muscle experiences a refractory period after contraction known as ‘autogenic inhibition’, where muscle relaxes due to neuro-reflexive mechanisms, thus increasing muscle length. Interestingly, electromyographic (EMG) studies have shown that muscle activation remains the same^{7,44} or increases after contraction.⁴⁵⁻⁵⁰ Some researchers have speculated that the associated increases in ROM are related to increased stretch tolerance^{51,52} rather than a neurological phenomenon. Some researchers suggest that Hoffman reflexes (H-reflexes) are depressed with a pre-contraction stretch.^{45,53} The H-reflex is an EMG measurement of the level of excitability of a muscle: lower H-reflexes are associated with lower excitability. It is possible that the lowered excitability levels may allow muscle to relax through the gamma motor neuron system despite an increased activation through the alpha system. Obviously, more research is needed to investigate these neurological effects of pre-contraction stretching.

COMPARING STRETCHING MODES

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Several authors have compared static and dynamic stretching on ROM, strength, and performance (See [Table 2](#)). Both static and dynamic stretching appear equally effective at improving ROM acutely or over time with training.⁵⁴⁻⁵⁷ Several authors have found no improvement in performance when comparing static and dynamic stretching.^{55,58-61} In contrast to static stretching, dynamic stretching is not associated with strength or performance deficits,

and actually has been shown to improve dynamometer-measured power^{27,62} as well as jumping and running performance.^{31,32,34,56,59,63,64}

Table 2.

Stretching Techniques Comparative Matrix, based on studies comparing at least 2 techniques.

The literature is conflicting regarding the effects of warm-up stretching prior to exercise. Static and dynamic warm-ups are equally effective at increasing ROM prior to exercise.^{56,57} Some researchers report static stretching after warm-up decreases performance,^{32,33,35} while others report no change or an increase in performance.^{32,38,64,65} While static stretching is generally followed by an immediate decrease in strength, static stretching performed before⁶⁶ or after warm-up⁵⁷ does not decrease strength. The volume of static stretching may also affect performance: Robbins et al³⁷ reported that 4 repetitions of 15-second holds of static stretching did not affect vertical jump, while 6 repetitions reduced performance.

A pre-stretch contraction has been associated with greater acute gains in ROM compared to static stretching in many studies;^{48,50,67-75} however, several studies show similar increases in ROM^{45,76-84} and performance^{77,81,82,84} when comparing pre-contraction stretching and static stretching. Both acute static stretching and pre-contraction stretching have been shown to decrease strength.^{26,83}

RECOMMENDATIONS

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Static, dynamic, and pre-contraction stretching are all effective methods of increasing flexibility and muscle extensibility; however, these modes may be more effective in specific populations. Several authors have noted an individualized response to stretching;^{48,56,60} therefore, stretching programs may need to be individualized.

Well-rounded Exercise Programs

For a general fitness program, the American College of Sports Medicine¹ recommends static stretching for most individuals that is preceded by an active warm-up, at least 2 to 3 days per week. Each stretch should be held 15-30 seconds and repeated 2 to 4 times.

Many exercise studies on older adults include stretching exercises as part of a well-rounded exercise program. Unfortunately, there is no clear dose-response for flexibility training in older adults because stretching interventions are often combined with strengthening, balance, and cardiovascular activities, making it difficult to isolate stretching's effectiveness. Older adults may need longer stretch times than the recommended 15 to 30 seconds; Feland et al⁸⁵ found that 60-second holds of static stretches were associated with greater improvements in hamstring flexibility in older adults compared to shorter duration holds. Ten weeks of static stretching of the trunk muscles was able to increase spinal mobility (combined flexion and extension ROM) in older adults.⁸⁶ Static stretching of the hip flexors and extensors may also improve gait in older adults.⁸⁷ Furthermore, the effectiveness of type of stretching seems to be related to age and sex:

men and older adults under 65 years respond better to contract-relax stretching, while women and older adults over 65 benefit more from static stretching.

Warm-up for Sports and Exercise

Stretching performed as part of a warm-up prior to exercise is thought to reduce passive stiffness and increase range of movement during exercise. In general, it appears that static stretching is most beneficial for athletes requiring flexibility for their sports (e.g. gymnastics, dance, etc.). Dynamic stretching may be better suited for athletes requiring running or jumping performance³⁰ during their sport such as basketball players or sprinters.

Stretching has not been shown to be effective at reducing the incidence of overall injuries.⁸⁸ While there is some evidence of stretching reducing musculotendinous injuries,⁸⁸ more evidence is needed to determine if stretching programs alone can reduce muscular injuries.³

Rehabilitation

Stretching is a common intervention performed during rehabilitation. Stretching is prescribed to increase muscle length and ROM, or to align collagen fibers during healing muscle.

Several researchers have investigated different muscle stretching techniques on subjects with tight hamstrings. Some authors report that both static and pre-contraction stretching are able to increase acute hamstring flexibility,^{47,54,89} while others suggest static stretching⁹⁰⁻⁹² or PNF stretching^{10,71} are more effective. It appears that 6 to 8 weeks of static stretching is sufficient to increase hamstring length.^{14,93,94}

Stretching is effective for the treatment of orthopedic conditions or injury; however, as with other populations, outcomes may be based on the individual patient. Static stretching has been shown to be more effective than dynamic stretching for those recovering from hamstring strains.⁹⁵ In addition, it has been reported that athletes with hamstring strains recover faster by performing more intensive stretching than by performing less intensive stretching.⁹⁶ Patients with knee osteoarthritis can benefit from static stretching to increase knee ROM;⁹⁷ however, PNF stretching may be more effective.⁶⁸ Chow et al reported that total knee replacement patients benefited from 2 weeks of either static, dynamic or PNF stretching to increase ROM.⁷⁶

Stretching is often included in physical therapy interventions for management of shoulder, back and knee pain. Despite positive outcomes of these types of studies and improvements in flexibility, it is difficult to isolate the effectiveness of the stretching component of the total treatment plan because the protocols usually include strengthening and other interventions in addition to stretching.

A recent review⁹⁸ of stretching for contractures found no improvement in joint mobility orthopedic-related contractures. Orthopedic contractures often result from shortness in non-contractile tissues such as capsuloligamentous structures rather than muscle tightness.

Researchers have shown that 12 months of stretching is as effective as strengthening exercises or manual therapy in patients with chronic neck pain.^{99,100} In addition, patients with chronic

musculoskeletal pain demonstrate an increased tolerance to stretch after 3 weeks of static stretching.¹² Lewit and Simons¹⁰¹ reported an immediate 94% reduction in pain associated with trigger points after applying a PIR technique. These studies support stretching in pain management programs.

Stretching appears to have no benefit for neurological patients who have had a stroke or spinal cord injury.⁹⁸ Because of a strong neurological component and long-standing muscle shortening associated with these conditions, it's no surprise that simple muscle stretching techniques are not effective.

SUMMARY

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The benefits of stretching seem to be individual to the population studied. Several factors must be considered when making clinical recommendations from the literature. To increase ROM, all types of stretching are effective, although PNF-type stretching may be more effective for immediate gains. To avoid decrease in strength and performance that may occur in athletes due to static stretching before competition or activity, dynamic stretching is recommended for warm-up. Older adults over 65 years old should incorporate static stretching into an exercise regimen. A variety of orthopedic patients can benefit from both static and pre-contraction stretching, although patients with joint contractures do not appear to benefit from stretching.

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