Flexibility has been the center of vigorous debate between researchers and clinicians. While various forms of flexibility exist, static stretching, and the protocols and implementation thereof, seem to be at the epicenter of the controversy as researchers seek to determine the mechanisms which may be affected by static stretching as well as the effects of static stretching on previously studied areas and theories related to the implementation of static stretching such as range of motion, risk of injury, strength and performance. This paper will review all areas of flexibility as well as current literature used to evaluate the effectiveness, influence or lack of influence on the factors of range of motion, risk of injury, strength and performance. This paper will also serve to explore various forms of flexibility and propose a continuum of flexibility implementation.
Flexibility

Outline:

I. Understanding Flexibility
II. Forms of Flexibility
III. Theories behind flexibility
   a. Flexibility and ROM
   b. Flexibility and injury prevention
   c. Flexibility and performance
   d. Flexibility and strength
IV. Critical evaluation of the research
   a. Limitations of the research
   b. Summary of the evidence
V. Improving the Effectiveness
   a. Assessment of need for flexibility
   b. Implementation of Flexibility
VI. Application Guidelines
   a. Flexibility and ROM
   b. Flexibility and Strength
   c. Flexibility and Performance
Flexibility
Current Concepts and Literature

Understanding flexibility has been challenging for researchers and clinicians alike. The purpose of flexibility has been theorized to include a vast array of benefits such as improving joint range of motion, correcting muscle imbalances, increasing neuromuscular efficiency and maintaining structural efficiency. Flexibility, using a general definition, is the normal extensibility of all soft tissues that allow full range of motion at a joint. For the purposes of this paper, we will be referring to flexibility as a broad term and refer more categorically when speaking of the type of flexibility being used, described as forms of stretching, to be titled self-myofascial release, static stretching, PNF or partner stretching, active-isolated stretching and dynamic stretching.

Understanding Flexibility

Flexibility as noted above is a general term and one needs to be more specific as to the type of flexibility being discussed. While there are various forms – the basic forms of flexibility are self-myofascial release (applying a 30 second sustained force to be placed upon a tender point in the muscle to create neuro-myofascial inhibition)\(^1\), static stretching (holding a stretch at end-range or first resistance barrier for 30 seconds), PNF stretching (partner assisted stretching using a form of contraction and relaxation of agonist muscle), active-isolated stretching (moving into and out of a range of motion and holding the end range no longer than 1-2 seconds) and dynamic stretching (using the strength of a muscle to move a joint through a full range of motion without compensation). For clarification and understanding of NASM’s Flexibility continuum, the forms of flexibility to be discussed are summarized in Figure 1.

While much of the current research is reserved towards forms of static stretching, using an integrated approach, different forms of flexibility can be used to derive added benefit to a training program, regardless of the goal of the

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**Figure 1**

Self-Myofascial Release

Self-myofascial release (SMR) is a flexibility technique that focuses on the neural and fascial systems in the body. Self-myofascial release concentrates on alleviating myofascial trigger points, areas of hyperirritability located within a band of muscle.\(^2\)

Static Stretching

Static stretching combines low force with long duration using autogenic inhibition. This form of stretching allows for relaxation and concomitant elongation of muscle. To properly perform static stretching, this requires holding the stretch at the first point of tension or resistance barrier for 30 seconds. It is theorized that this form of flexibility decreases muscle spindle activity and motor neuron excitability.

Active-isolated Stretching

Active-isolated stretching uses agonists and synergists to dynamically move a joint into a range of motion. This form of flexibility is speculated to decrease motor neuron excitability using reciprocal inhibition of the muscle being stretched. The technique used to implement active-isolated stretching is to move into the range of motion holding the end range of the stretch 1-2 seconds, performing 5-10 repetitions of the motion.

Dynamic Stretching

Dynamic stretching uses the force production of a muscle and the body’s momentum to take a joint through the full available range of motion. Dynamic stretching consists of performing 3-10 dynamic stretches for 10 repetitions of the movement being performed.
Each form of flexibility (as listed in Figure 1) has a role in increasing range of motion, helping to prevent injury, and enhancing strength and performance. (See Figure 2)

The National Academy of Sports Medicine incorporates flexibility into all integrated training programs and considers flexibility as an overall continuum utilized to improve neuromuscular efficiency (see Figures 2 & 3).

**Theories behind Flexibility**

Flexibility has been the subject of debate for several decades leading researchers to continue to study the effects, duration and methodologies behind stretching. To date, this subject might be one of the most widely diverse and profusely studied topics related to human performance. Many believe static stretching to provide the benefit of increased range of motion and decreased muscle stiffness (greater muscular compliance allowing for an increase in eccentric storage and release of energy). In accordance, static stretching is thought to increase neuromuscular efficiency through restoring proper muscular balance, force-couple relationships and decreasing potentially harmful movement alterations as a result (such as synergistic dominance), increase motor neuron facilitation which may, in effect increase performance measures such as balance, coordination, strength and power. While, on the contrary, many believe static stretching to reduce muscle contraction times, force production and alter neuromuscular control – all of which may lead to a lack of coordination and potential injury. Researchers argue that static stretching may negatively affect strength, through decreased motor neuron firing, and performance due to increased slack, dampening or reduced reaction times and hence, may be contraindicated as a warm-up procedure. Various research studies suggest that “stretching” may not provide the benefits many researchers and clinicians propose such as a decreased risk of injury and increased performance gains. Research has spanned various avenues looking at both the acute and chronic effects of stretching; testing various methodologies, stretching durations, techniques and even disputed the mechanisms behind stretching. Given the vast amount of information concerning
flexibility, research literature for the topics of Flexibility and Range of Motion, Flexibility and Injury Prevention, Flexibility and Strength and Flexibility and Performance, were reviewed and categorized using inclusion criteria listed in Table 1.

Little research supports many of the claims surrounding flexibility, however various studies and clinical evidence show that flexibility may provide an important component to an integrated training program. As to be discussed in this paper, flexibility has a far greater reach and potential than current research has been able to analyze and while the results of various studies may seem contrary to the proposed beneficial effects of flexibility, the analysis of methods, results and isolated implementation methodology requires further investigation and study.
Table 1

<table>
<thead>
<tr>
<th>Topics</th>
<th>Inclusion and Exclusion Criteria</th>
<th>Electronic Literature Search</th>
<th>Search Results</th>
<th>Evaluating Articles and the Body of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility and Range of Motion, Flexibility and Strength, Flexibility and Performance</td>
<td>Inclusion criteria included randomized control trials or clinical trials comparing a stretching intervention with a control or sham treatment. Studies must have quantified ROM both pre- and post-treatment. If the study design was fully within-subjects, subjects must have received both the control condition and the treatment condition(s) and been pre- and post-tested on all occasions. Studies were excluded if comparisons were made between legs (on the same subject) or if pre-test served as the control.</td>
<td>Research studies were identified by PubMed (MEDLINE), Cumulative Index to Nursing and Allied Health Literature (CINAHL), SPORTDiscus, and Cochrane Library searches with no date restrictions. Search terms included: Flexibility Stretching Stretch Stretches combined with motion</td>
<td>A total of 11 studies for range of motion, 5 for strength, and 4 for performance were identified that met all of the inclusion criteria (20 studies total). The articles were abstracted and the following information was gathered:</td>
<td>A total of 73 articles were reviewed and given a PEDro score. Articles that received less than a 4 on the PEDro scale were excluded from the review.</td>
</tr>
</tbody>
</table>

The search was limited to human subjects, English-language journals and clinical trial or randomized control trials. This search yielded a total of 731 articles. The titles of these articles were reviewed to assess eligibility, followed by a review of the abstract. Those articles that fit the inclusion criteria, based on the abstract review, were individually reviewed to confirm eligibility for inclusion.
Understanding Flexibility’s Role in Influencing Range of Motion

The debate surrounding flexibility and range of motion appears to be centered on a few factors such as type of stretch (static stretching or PNF/neuromuscular stretching), duration of the stretch required to increase range of motion and the mechanics of the stretch (how does stretching increase range of motion). Researchers have sought to determine what form of flexibility creates the greatest range of motion around a joint, an understanding of the mechanics of stretching along with an understanding of the duration of stretch required to see a significant change in range of motion. The majority of the research studies that met the inclusion criteria (see Table 2) point to increased range of motion when using an acute or chronic static stretching program. In fact, according to several studies, when increasing range of motion, PNF stretching (a form of static stretching that uses reciprocal inhibition – contracting the agonist muscle to reduce the motor neuron activity to the antagonist muscle) created the largest gains in range of motion.²⁻⁴ Sady (1982), found PNF stretching superior to all types of flexibility when used to increase range of motion when tested on the trunk, shoulder and hamstrings.² In a study by Decicco (2005), PNF stretching, whether performing the contract-relax-contract technique or the hold-relax-contract technique, created significant range of motion differences over a 6-week span when compared to traditional static stretching.³ In addition, a study by Schuback (2004), concluded that when tested head-to-head against static stretching implemented in a home program, PNF stretching reigned superior. In this study they found that self-applied PNF stretching using a contract-relax-contract method increased range of motion more than self applied static stretching.⁴

As to the mechanics of stretching, more research needs

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**Table 2 - Summary of studies that met inclusion criteria for flexibility and ROM**


to be done to fully understand the mechanisms behind stretching. Current theories equate increased range of motion to structural changes and/or changes in stretch sensation. In fact, the truth may lie somewhere in combination. Some theorize that structural changes take place when performing static stretching such as decreased stiffness of the muscle tendon unit and passive resistive force \(^5\) while others hypothesize that the muscle structure does not actually change, but the stretch sensation leads to increases in range of motion. The greater stretch tolerance might lead to increased range of motion around a joint. \(^6\) Using an examination of muscle stiffness (ratio of change in force to change in angle) as a guide, theoretically, if muscle stiffness increased in combination with increased range of motion, then changes in muscle structure would have occurred. The muscle stiffness theory hypothesized by Reid and McNair in their 2004 published study, found that a six-week hamstring-stretching program performed one time per day, held for 30 seconds, repeated three times, increased knee extension range of motion, passive resistive force and stiffness. \(^5\)

This was also shown in the research of Gadjosik (1991, 2001)\(^7,8\) “who suggested that the increases in hamstring length may be due to possible increases in the number of sarcomeres in series”. \(^5\) While these findings require more study, many postulate these changes to be influenced by the intensity of the stretching protocol. In the study performed by Bjorklund, a decrease in stretch sensation of the rectus femoris muscle was found to increase range of motion of knee flexion; there was no increase in range of passive knee flexion, and hence, passive stiffness was thought to be unaffected. \(^6\) This study corresponded to the work of Magnussen (1996) which found evidence of sensory adaptation from stretching. \(^9\) This leads researchers to believe that sensory adaptation is an important factor in increasing range of motion from static stretching. Researchers did not rule out changes in muscle stiffness and stated that changes in sensation may precede changes in stiffness. \(^6\) Of interest is the reference to the muscle being stretched. As discussed in Bjorklund’s study, “angle of pennation, cross-sectional area and shortening velocities are important factors for the passive properties of a muscle”. \(^6\) Overall, more research on various muscles, intensities and protocols will help researchers understand the underlying mechanism behind stretching and its role on increasing range of motion.

While various stretching protocols exist, researchers have begun to understand the effect of stretching duration on increasing ranges of motion. In an important study by Bandy (1994), the duration of holding a stretch was measured against shorter or longer static stretching protocols. Thirty seconds of holding a stretch, once a day, five days a week for six weeks resulted in increased range of motion at a joint. \(^10\) However, in contrast to Bandy’s findings, some researchers argue about the implementation of static stretching. In a study done by Bazett-Jones (2005), acute bouts of static stretching (using 3 sets of 30 second holds) showed no effects on increasing range of motion\(^11\) as did the research of Youdas (2003) which challenged the chronic effects of static stretching finding no significant changes in range of motion in the gastrocnemius after implementing a 6-week stretching regimen (30 second duration stretches, performed once a day, 5 days a week). \(^12\) Given the differences in research results, it is important to analyze a few different factors that may affect the relationship between static stretching and range of motion.

While much more research must be done to understand some of the underlying factors behind stretching and increasing range of motion, there are a few determinants that NASM uses to understand the role of static stretching on increasing range of motion. First, is the determination of muscle
imbalances which may affect range of motion. In a study done by Clark (1999), researchers found that when testing the range of motion of the hamstrings, stretching the opposite muscles, the quadriceps, increased range of motion at the hips. The quadriceps were found to be tight, which created an anterior pelvic tilt of the hips, in effect increasing the length of the hamstrings which decreased range of motion for hip flexion. This study showed that flexibility and range of motion requires a thorough and integrated assessment process looking at all aspects or barriers to range of motion and not an isolated look at a singular muscle. Second, the implementation of the method on certain muscles is a factor. When looking at the contrasting studies of Bandy and Youdas, Youdas implemented an exact replica of the methodology of Bandy, but performed the stretches on the gastrocnemius muscle, looking at range of motion of dorsiflexion versus Bandy’s study on the hamstrings. While Youdas found that the stretching regimen did not produce the same results as Bandy (no significant increase in range of motion) there is a significant point to consider. The calf muscles may require a greater or longer stretch protocol due to their daily positioning (the calf muscles are potentially more frequently engaged during daily activities and can be influenced by the footwear of individuals) and functional requirements. This is not to say that the hamstrings are not enlisted as frequently during daily activities, but the question behind the functional muscle differences and influence of stretch on muscle differences remains. Given the constant strain on the calf muscles, a stretching intervention program for increasing dorsiflexion might require a greater amount of stretching each day than the hamstrings which Bandy tested in his study. Of importance is also the inclusion criterion of Youdas’ study. The study included healthy subjects with no lower-extremity dysfunction assessed by gait observation. Would the same static stretching protocol have influenced individuals with ankle restrictions such as increased pronation? Additionally, research has still to consider the integrated effects of flexibility. An isolated stretching regimen may not create the required effects on increasing and sustaining range of motion. In fact, it is NASM’s position that a proper flexibility program would require the incorporation of a strengthening program for the antagonist muscle immediately after performing flexibility. Each joint moves as a result of length-tension and force-couple relationships surrounding a joint. If one muscle is short and overactive, its functional antagonist may be long and underactive. Given this relationship, a proper flexibility program would require implementing a corrective strengthening program to help a joint increase range of motion and re-establish normal length-tension and force-couple relationships. Overall, NASM concurs with current research which has found static stretching to increase range of motion; however, using clinical evidence to support their stance, NASM believes that a proper flexibility program would also require implementation of a corrective strengthening program to enhance range of motion. See Table 7 for application guidelines for help in implementing a flexibility program to increase range of motion.
Understanding Flexibility’s Role in Influencing Strength

Recent literature has created controversy within the sports medicine community about the influence of stretching on muscular strength. These articles have concluded that stretching may negatively influence strength. This conclusion has started a debate among clinicians about the role of stretching before activity. A decrease in muscular strength may be detrimental to performance or increase the risk of injury during high demand athletic events. According to research stretching causes several changes within the muscle. It decreases stiffness of the muscle, increases compliance, and may cause physiological damage by breaking the bond. Stretching is believed to affect the muscle in one of two ways: (1) by affecting mechanical properties including stiffness or (2) by affecting the neuromuscular control of the muscle via control mechanisms (Marek 2005).

Static stretching has become commonplace in most exercise and performance activities, usually performed prior and post-exercise or sporting activity. Historically, clinicians have used static stretching to increase range of motion and decrease muscle stiffness which theoretically will prevent injury and enhance performance through optimal neuromuscular efficiency. However, given the changes that static stretching may create in a muscle, researchers have questioned the practice of using static stretching prior to a strength activity, hypothesizing that static stretching may negatively influence strength.

While the effects of static stretching on strength may still be up for debate amongst clinicians, a literature review of five relevant research studies (see Table 3) has concluded that static stretching negatively influences strength. Researchers point to decreases in motor unit activation post-stretch, decreasing maximal voluntary contractions (Fowles et al., 2000). Marek determined that static stretching reduced both muscle strength and power and in fact altered the mechanical properties of the muscle (using EMG and MMG data). His study showed decreased EMG activity and increased MMG activity – leading researchers to believe that static stretching may reduce activation of a muscle and decrease muscle stiffness (Marek et al., 2005). In fact, whether assisted or self applied, a study performed by Kokkonen (1998) determined that even short bouts of static stretching (15 second holds with 15 second relaxation times) reduced strength approximately 7-8% in the muscles tested (hip, thigh and calf). Knudson’s research concurred with these results showing that 40 seconds of static stretching (done in bouts of 10 seconds for four repetitions) decreased strength when tested on the wrist flexors (Knudson et al., 2005). Of great interest was the two studies performed by Fowles (2000) and Power (2004) which tested the lasting effects of static stretching up for up to 2 hours.

Table 3 - Summary of studies that met inclusion criteria for Flexibility and Strength

These studies found that static stretching not only affected strength immediately after but 60 to 120 minutes post-stretch (Fowles et al., 2000; Power et al., 2004). These strength deficits shown up to 120 minutes post-static stretch are significant in determining the viability of including static stretching into a warm-up. However, despite the research there are a few factors to consider. Overall, research shows that static stretching done prior to strength activity decreases strength and may affect strength up to 2 hours post-stretch. Researchers have determined that static stretching should not be performed in a warm-up if individual is going to participate in high-level strength activities. NASM concurs with the researchers however limits agreement to a few factors. One, if muscle imbalances exist strength might also be limited by decreased range of motion and neuromuscular inefficiency (improper length-tension relationships altering force-couple relationships – leading to altered reciprocal inhibition). Given this – static stretching should be incorporated and addressed to areas where tight/overactive muscles are shown when tested using a movement assessment. Two, improper firing of synergists during an exercise (synergistic dominance) can lead to faulty movement patterns and in effect, limit strength. Incorporating static stretching to address areas which show altered reciprocal inhibition (in turn addressing synergistic dominance) may enhance strength by increasing neuromuscular efficiency (allowing for greater recruitment of motor units).

The acute effects of static stretching have led NASM to determine pre-activity flexibility should be limited to active-isolated and dynamic stretches unless muscle imbalances are present that may impede proper movement and limit range of motion. If static stretching is used to address these imbalances, it must be followed with muscle activation to the antagonist and dynamic stretching to increase neuromuscular efficiency and motor neuron excitability pre-activity. See Table 8 for application guidelines to help in implementing a flexibility program to enhance strength.

**Understanding Flexibility’s Role in Influencing Performance**

As noted above, static stretching causes several changes within muscle. It decreases stiffness of the muscle, increases compliance, and increases length by breaking chemical bonds. If these theories are true then performance may be negatively affected by stretching. If a muscle has decreased stiffness then there may be an increased time delay between initial contraction and force production that can be thought of as “taking up the slack” within a muscle. Additionally, altered neuromuscular control could result in lack of body control or coordination and lead to injury during high risk maneuvers. In contrast, previous research had also concluded that stretching is believed to improve performance during running and sprinting. Evidence suggests that static stretching (done prior to activity) does inhibit muscular strength as discussed in the previous section but it is unclear if decreased strength equates to decreased performance. For purposes of this paper, performance was defined as vertical jump or other measures related to performance such as reaction time, movement time, and balance. Eight research studies met the inclusion criteria to be reviewed in this paper (See Table 4).
The debate amongst many professionals centers on the use of static stretching (one form of flexibility) prior to performance. There are many who have determined that static stretching negatively influences performance. In fact research has shown decreases in balance, reaction times, movement times (Behm 2004) and a decrease in jump height (Young 2001). However, there exist some contradictory studies which reveal that static stretching may increase lower-limb stiffness resulting in higher countermovement jumps (Hunter 2002) and potentially having no impact on vertical jump heights (Unick 2005). Of potential importance is the varied approach to the subject of pre-activity static stretching. Hunter presented a study that looked at the effects of static stretching over a duration of weeks (static stretching integrated into a 10-week program) versus the acute effects of static stretching on performance (done immediately following the stretching protocols). The acute effects may not equate to decreases in muscle stiffness and therefore the results may not match those of Young. Shrier found in his review of the literature that seven studies found beneficial effects from chronic or regular stretching programs (showing improved range of motion), with only two studies showing no effect (based on tests of running economy). In fact, Shrier found clinical evidence which “strongly suggested that regular stretching increases isometric force production and velocity of contraction”. Kokkonen and colleagues found in their 2007 study that regular stretching protocols (40 minutes of static stretching per day, 3 times per week for 10 weeks) increased flexibility, strength (23.9%), endurance (29.5%) and power in the lower extremities. These studies show that flexibility may have a beneficial influence on performance and performance measures when used on a regular basis. The influence of a regular stretching program may equate to increases in range of motion, potential increases in stretch-induced hypertrophy and increases in power due to increases in muscle length (increased contractile velocities and forces generated at a given shortening velocity). Gadgosik found significant increases in agility and walking tests after implementing a regular stretching intervention program (2004) while Wilson (1992) found significant improvement in concentric and eccentric strength following an 8-week stretching regimen, finding a reduction in the stiffness of the series elastic components.

Table 4 - Summary of studies that met inclusion criteria for Flexibility and Performance


Overall, research shows that performance is influenced by static stretching and may decrease jump height, balance, reaction times and movement times when used prior to activity. The acute effects of static stretching have led NASM to determine pre-activity flexibility should be limited to active-isolated and dynamic stretches unless muscle imbalances are present that may impede proper movement and limit performance. If static stretching is used to address these imbalances, it must be followed with active-isolated and/or dynamic stretching to increase neuromuscular efficiency and motor neuron excitability pre-activity. However, this does not negate the use of a stretching regimen altogether. The regular effects of stretching have been shown to enhance performance \(^{23-26}\) and should therefore be used within an integrated training program to increase strength, power and endurance (essential components of increased performance). Research has shown that altered movement as the result of muscle imbalances (such as altered length-tension relationships, altered force-couple relationships and concomitant altered arthrokinematics) leads to altered balance, proprioception and neuromuscular efficiency – all of which is required for optimal performance.\(^{27,28}\) Alterations in the structural and functional efficiency of the human movement system affect the quality of movement and hence may perpetuate faulty movement. In turn, this may lead to decreased strength, balance, reaction times, and ability to generate higher levels of force (decreased rate of force production due to a decrease in motor unit recruitment and synchronization due to muscular imbalances) required for sport. Furthermore, while some research suggests that an acute bout of static stretching may inhibit muscular strength when performed in isolation, research that is currently underway at the University of North Carolina is beginning to show that a systematic approach that includes; inhibition (foam roll), lengthening (static stretching), activation (active stretching), and integration (dynamic stretching) may improve human movement imbalances, decrease injury risk, and improve performance. See Table 9 for applications guidelines to help in implementing a flexibility program for performance.

**Understanding Flexibility’s Role in Injury Prevention**

Many researchers believe flexibility may help prevent injury. However, much of the current research has begun to dismiss the theory, suggesting that flexibility has no or little influence on preventing injury.

Those who postulate the injury prevention benefit look to anatomy and biomechanics to present their case as muscles with imbalances create joint stress, altering the normal arthrokinematics, creating altered neuromuscular control, potentially creating synergistic dominance and which may, over time, lead to injury. (See Figures 4 & 5)
Maintaining muscular balance is theorized to be a key to optimal movement. Given the interplay of joints and their reliance on muscular and nervous system input to move correctly, maintaining optimal
muscle lengths would seem beneficial to preventing injuries. However, as noted earlier, much of the research points to the acute effects of stretching prior to exercise and has found that acute stretching shows little to no improvement or influence on preventing injury. As noted in the research of Andrish (1974) and Pope (1998, 2000), stretching the calves or lower extremities did not influence the rate of lower-limb injuries such as shin splints or plantar fasciitis (injuries theorized to be related to tight or overactive calf and lower extremity muscles). 29, 30, 31 On the contrary, the work of Shrier (2002) showed that regular bouts of stretching, as opposed to stretching right before exercise, may reduce the risk of injuries. 32 Hartig and Henderson showed that increasing the flexibility of the hamstrings reduced the number of injuries in military recruits as tested over a 13-week basic training course. Injury rates were reduced to 16.7% in the stretching intervention group versus 29.1% in the control group. 33 Amako and colleagues (2003) found that a regular static stretching regimen of military recruits reduced the rate of muscle/tendon injury and incidents of low back pain after the first month of implementation. 34 Hilyer (1990) studied the effect of flexibility on injury and cost (due to time spent injured and medical care). His study revealed a small, but significant difference on the intervention group, showing less severity of injury and lost time costs. 35 Overall, there is moderate evidence that the acute effects of pre-activity stretching may not reduce the incidence of injury, however, the regular effects of implementing a flexibility program show reduced incidence of injury, less time lost costs and a reduced severity of injury focused more on muscle/tendon injuries versus joint injuries.

Critical Evaluation of the Research

Limitations of the Research

In review of the literature surrounding flexibility, some limitations surfaced. First, much of the research has been performed on individuals who do not show limitations in flexibility. Many tests for assessment were done at isolated joints and done passively, not assessing the dynamic movement which may be impeded by muscle imbalances. Acute pre-exercise stretching, while it has been shown to have negative effects, may benefit those with flexibility limitations shown through a variety of assessment procedures (which in turn may show concomitant movement limitations such as decreased joint range of motion or

Table 5 – Summary of studies that met inclusion criteria for Flexibility and Injury Prevention


altered arthrokinematics). These acute bouts of stretching may in fact increase performance through increasing range of motion, decreasing synergistic dominance and increasing neuromuscular efficiency. In fact, pre-exercise assessments of movement may help to determine the need for flexibility. Using an integrated and dynamic assessment process such as gait observation or the Overhead Squat Assessment (see Figure 5) or Single-leg Squat (see Figure 6) may help to determine the areas where a flexibility intervention may be necessary prior to activity to enhance movement or performance. Research by Vesci, Bell and Zeller have demonstrated the significance of incorporating kinematic assessments to understand movement deficiencies. As noted in the research by Zeller (2003) the single-leg squat kinematic assessment, generally used to screen for hip strength and core control, showed increased adduction in females helping researchers further investigate the variance of factors affecting the large number of ACL injuries in female athletes. Bell (2007) showed that the use of the double-leg squat assessment assisted researchers in understanding the role of limited dorsiflexion range of motion in influencing knee valgus. In fact, researchers found that limited dorsiflexion had an influence on knee valgus. Vesci, utilizing the double-legged squat assessment, showed increased hip adductor activity and limited ankle dorsiflexion range of motion in those who displayed knee valgus. As utilized by NASM, individualized assessments are required to determine what type of intervention strategy, such as flexibility with concomitant corrective strengthening, may be required by each individual. Only where movement limitations are identified should such an intervention be implemented.

However, this brings about the second limitation of the research. Flexibility has been studied as an isolated exercise technique. Research has been focused on stretching individual muscles to create greater length or range of motion such as knee extension or flexion. In looking at the body as a kinetic chain, muscle imbalances are part of an integrated imbalance, muscle shortening of an agonist on one side of a joint creates a weakening or lengthening of the opposite side antagonist muscle – altering the force-couple relationship. Given that the human movement system, and hence muscles and joints, do
not work in isolation, isolated interventions may not create the necessary strategy to correct the imbalances. An integrated approach may be the necessary procedure to effectively enhance range of motion, strength and performance, while simultaneously helping to reduce the incidence of injury. (See Figure 3, p.4)

Lastly, the major forms of flexibility that have been studied focus on variances of static stretching. Some research has touched on the potential benefits of active-isolated and/or dynamic stretching prior to activity, but as of yet, researchers have not yet investigated the specific effects of incorporating these forms of flexibility into a warm-up. Would these forms of flexibility, theorized to enhance range of motion while simultaneously exciting motor neuron activity and increase neuromuscular activity, enhance strength and performance? As noted in Figure 2, and defined in Figure 1, the flexibility continuum as proposed by the NASM, takes a comprehensive approach to flexibility, utilizing different forms of flexibility based on the activity and need of each individual client.

Summary of the Evidence

As indicated by the aforementioned review of research and literature surrounding flexibility, the NASM has determined the following:

- There is moderate evidence to indicate that regular stretching improves ROM, strength, performance and decreases injury risk in healthy individuals without identified limitations in flexibility.
- There is moderate evidence to indicate that acute, pre-exercise stretching performed in isolation decreases strength and performance and does not affect injury risk in healthy individuals without identified limitations in flexibility.

Evidence-Based Recommendations

- Regular stretching can be used as an exercise modality to improve ROM, strength, performance, and prevent injury.
- Acute, pre-exercise static stretching, performed in isolation immediately before tasks requiring maximal effort may result in decreased strength and performance.
Improving the Effectiveness of Flexibility

As noted earlier in this paper, various components are required for an integrated approach to improving the effectiveness of flexibility training. Since a majority of the research isolates stretching, it is important to understand that flexibility is one component to maximizing performance and decreasing injury risk. The first step is proper assessment protocols. Research, overall, has taken a “one size fits all” approach to evaluating the need for flexibility. As most clinical professionals can attest, individuals require individualized assessment to extrapolate needs. The human movement system works as an integrated kinetic chain and evaluating one isolated component of such may not determine the flexibility needs of the client overall. As shown in the previously mentioned study by Clark, when evaluating the extensibility of the hamstring, Clark’s study noted that the positioning of the pelvis played a role in the range of motion of the hamstring and in effect, stretching of the hip flexors increased the range of motion of the hips. This shows that muscular interaction affects range of motion and isolated assessment may not tell the whole story. Utilizing a variety of assessments for passive range of motion (using goniometry) and active/dynamic range of motion (gait assessment, overhead squat assessment, single-leg squat assessment) can help to ascertain the limitations in movement of an individual and help create a customized strategy to effectively reduce injury, increase strength and performance.

The first step is to incorporate an Integrated Model to reduce the risk of injury and increase performance. As such, this begins with assessment to identify muscle imbalances (see Figures 5 & 6). These assessments work to understand muscle tightness and concomitant muscle weakness through the identification of faulty movement patterns. The next step is to incorporate a corrective strategy designed to alleviate imbalances and increase neuromuscular efficiency by combining both stretching and strengthening to comprehensively facilitate re-alignment of the human movement system. Using Table 6 as a guide to working with common imbalances, initiate a corrective exercise strategy that incorporates inhibiting the overactive musculature, stretching the overactive musculature, activate the underactive musculature and integrating the affected areas into compound functional movement (as shown in Figure 3, p.4). This table shows example strategies for the movement compensations shown. Individuals require an individualized intervention strategy based on the imbalances or compensations they present with.
In conclusion, more research must be done to provide a conclusive statement about the relationship between static stretching and the acute and chronic effects on range of motion, strength, performance and risk of injury. While conflicting research exists, it is important to understand the deficits that remain in current research studies and examine the potential benefits that may arise given a paradigm shift in thought about the role of flexibility. Currently, research is underway to test the effects of an integrated flexibility program and to better understand the different roles of the variety of flexibility methods.
available to researchers and clinicians. Overall, there is evidence, that flexibility, implemented correctly, can be beneficial in increasing range of motion, enhancing strength and performance as well as reduce the risk of injury.
Application Guidelines

Based on the review of the literature and research discussed above, the NASM has put together guidelines for application of flexibility. Tables 7-9 show implementation strategies for Flexibility and Range of Motion, Flexibility and Performance and Flexibility and Strength.
Table 7

Training Tips for Flexibility and Range of Motion:

1. Always begin a program for flexibility with movement assessments such as the Overhead Squat and/or the single-leg squat. These assessments help determine the muscles that need to be addressed in a flexibility program. If a muscle is overactive or tight – it may be impeding or altering proper movement and as such need to be corrected to enhance movement. See Table 6 for a list of general movement impairments and how to address each.

2. Static Stretching
   a. Indications
      i. Warm up
         1. Foam roll areas that appear hyperactive or tight as determined by the assessment process. Tender spots indicate areas of muscle hypertonicity and must have sustained pressure on the “knot” to help create autogenic inhibition.
         2. Static stretching should only be used on areas that are determined as tight/overactive from the assessment process and each stretch should be held for 30 second duration at end-range.
      ii. Cool down
         1. Static stretching should be used post-workout to return muscles to normal resting lengths and should be performed on the major muscles utilized during the workout.

3. Proprioceptive Neuromuscular facilitation (PNF) Stretching
   a. Indications
      i. Post-rehabilitation/Corrective Exercise program
         1. PNF stretching should be utilized by professionals trained in PNF techniques included but not limited to hold-contract-relax, and contract-relax-contract techniques. These techniques have been shown to provide an acute increase in range of motion – important in working with clients in need of enhancing range of motion, and assists in teaching proper reciprocal inhibition and neuromuscular efficiency. PNF stretching can be incorporated prior to workout on muscles determined to be short/overactive and may be inhibiting proper movement.
      ii. Cool-down/post activity or workout
         1. Used post-workout to return muscles to resting lengths.

<table>
<thead>
<tr>
<th>1 Foam Roll</th>
<th>2 Static stretching</th>
<th>3 PNF Stretching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find a tender spot in overactive areas and sustain pressure on tender areas for 30 seconds.</td>
<td>Hold each stretch (at first resistance barrier) for 30 seconds (stretches determined by results of movement assessment).</td>
<td>Passively move limb to the first resistance barrier. Instruct client to apply a 25% maximal voluntary contraction of the muscle being stretched (agonist) for 7-15 seconds. After relaxation of the brief contraction, move the limb into the newly created range of motion and hold for 20 seconds. Repeat 3 times.</td>
</tr>
</tbody>
</table>
Table 8

Training Tips for Flexibility and Strength:

1. Always begin a program for flexibility with movement assessments such as the Overhead Squat and/or the single-leg squat. These assessments help determine the muscles that need to be addressed in a flexibility program. If a muscle is overactive or tight – it may be impeding or altering proper movement and as such need to be corrected to enhance movement. See Table 6 for a list of general movement impairments and how to address each.

2. Static Stretching
   a. Indications
      i. Warm up
         1. Foam roll areas that appear tight or overactive as indicated by the assessment process.
         2. Static stretching should only be used on areas that are determined as tight/overactive from the assessment process
         3. Static stretching (if incorporated before a strength workout) should be followed by muscle activation of the functional antagonist of the muscle just stretched.
      ii. Cool down
         1. Static stretching should be used post-workout to return muscles to normal resting lengths and should be performed on the major muscles utilized during the workout.
   b. Contraindications
      i. Prior to activities requiring maximal effort.

3. Active-Isolated and/or Dynamic Stretching
   a. Indications
      i. As a warm up by themselves if no muscle imbalances are present.
      ii. As a warm up after static stretching if muscle imbalances are present.
      iii. Prior to a strength workout if no muscle imbalances are present.
      iv. Prior to activities requiring maximal effort.
   b. Contraindications
      i. As a warm up by themselves if muscle imbalances are present.

4. Acute Variables

<table>
<thead>
<tr>
<th>Flexibility Protocols Used BY NASM</th>
<th>2 Dynamic Stretching</th>
<th>3 Dynamic Stretching</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Static stretching</td>
<td>1-2 sets; hold each stretch for 1-2 seconds for 5-10 repetitions</td>
<td>1 set; 10 repetitions; 3-10 exercises</td>
</tr>
<tr>
<td>Hold each stretch for 30 seconds (stretches determined by results of movement assessment)</td>
<td>Example: Kneeling hip flexor stretch</td>
<td>Example: Active hip flexor stretch</td>
</tr>
</tbody>
</table>

Example: Front Lunge
### Table 9

**Training Tips for Flexibility and Performance:**

1. Always begin a program for flexibility with movement assessments such as the Overhead Squat and/or the single-leg squat. These assessments help determine the muscles that need to be addressed in a flexibility program. If a muscle is overactive or tight – it may be impeding or altering proper movement and as such need to be corrected to enhance movement. See Table 6 for a list of general movement impairments and how to address each.

2. Static Stretching
   a. Indications
      i. Warm up
         1. Foam roll areas that appear tight or overactive as indicated by the assessment process.
         2. Static stretching should only be used on areas that are determined as tight/overactive from the assessment process.
         3. Static stretching should be followed by muscle activation to the antagonist of the muscle just stretched.
      ii. Cool down
         1. Static stretching should be used post-workout to return muscles to normal resting lengths and should be performed on the major muscles utilized during the workout.
   b. Contraindications
      i. Prior to a sporting event if no muscle imbalances are present.
      ii. Prior to activities requiring maximal effort.

3. Dynamic Stretching
   a. Indications
      i. As a warm up by themselves if no muscle imbalances are present.
      ii. As a warm up after static stretching if muscle imbalances are present.
      iii. Prior to a sporting event if no muscle imbalances are present.
      iv. Prior to activities requiring maximal effort.
   b. Contraindications
      i. As a warm up by themselves if muscle imbalances are present.

4. Acute Variables

<table>
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<tr>
<th>1 Foam Roll</th>
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<th>2 Dynamic Stretching</th>
</tr>
</thead>
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<td>Hold each stretch for 30 seconds (stretches determined by results of movement assessment).</td>
<td>1 set; 10 repetitions; 3-10 exercises.</td>
</tr>
</tbody>
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References


