Effects of Myofascial Release on Human Performance
A Review of the Literature

Anthony D'Amico
and
Christopher Morin

Abstract

Myofascial releasing rollers are muscle massage devices used by athletes, fitness enthusiasts, and those recovering from injury to enhance functional ability. OBJECTIVES: The purpose of this study was to assess the acute effects of self myofascial releasing rollers on muscle strength, power, and flexibility compared to static stretching and control. STUDY DESIGN: Thirteen adult recreationally trained subjects consented to participate in a 3-week, counterbalanced repeated measure study, which consisted of 3 testing sessions (1 baseline and 2 data collection) scheduled 2 weeks apart. METHODS: Criterion measures of range of motion (ROM) of the hamstring musculature both seated and supine, isometric strength of the knee flexors (STR), and one leg jump power test (JUMP) were measured at one week before treatment conditions (baseline 1), before treatment conditions (baseline 2), and after treatment conditions of self-myofascial releasing (SMR) and static stretching (SS). Baseline 1 and 2 acted as the control (CONT). Statistical analyses involved a t test determining significant differences in treatments. RESULTS: There was no significant difference between SMR and SS in ROM. There was a significant difference between SMR and SS in STR. There was also a significant difference between SMR in JUMP. CONCLUSIONS: SMR increases ROM as much as SS. SMR increases isometric strength and increases jumping ability compared to SS and a control. IMPLICATIONS: SMR can improve acute ROM and may be used with or in replacement of SS towards

improving ROM. SMR may be used as an aid before strength or power performance.

Effects of Myofascial Release on Human Performance

A Review of the Literature

The purpose of this study is to determine if self myofascial releasing rollers, a common therapeutic tool used today have an effect on human performance and a rating of perceived function. At this time it is unclear whether self myofascial release has any tangible effect on any measurable physical attribute. After a medline search there appears to be no research study that has investigated the effects of self myofascial releasing rollers on human performance.

Despite the lack of scientific evidence on behalf of self myofascial release, the technique has a large following. Many fitness professionals now incorporate some form of the technique in their programming, be it for warm-up, performance enhancement, or pain relief. Scientific evidence pertaining to myofascial releasing would be immensely helpful in determining the merit of this technique from a research standpoint. As it stands, myofascial release is deemed beneficial based primarily on anecdotal evidence.

On a larger scale, as participation in fitness activities grows among the athletic and general population, a need for some consensus on proper exercise protocol is apparent. Research is regularly conducted to measure the efficacy of various strength, cardiovascular and speed enhancing techniques. Less attention is generally paid to the pre-exercise “warm-up” portion of an exercise session, from a practical and research standpoint. This could be due to the difficulty of attributing a measurable training effect to a warm-up protocol as opposed to a training protocol. Given the constant search for the most effective ways to exercise, it stands to reason that it may be worthwhile to search for the most effective ways to warm-up for exercise as well.

Generally speaking a warm-up serves to increase core body temperature making the muscle and soft tissues more pliable. The warm-up also prepares the circulatory and nervous systems for activity, where it may possibly prevent an abnormal cardiovascular event. Specifically, the American College of Sports Medicine (ACSM) in their own guidelines suggests that a warm up facilitates the transition from rest to exercise, where it stretches postural muscles, increases blood flow, elevates body temperature, dissociates more oxygen, and increases metabolic rate to the requirements demanded of the increased activity (ACSM, 2006). The ACSM further states that a warm up may reduce the susceptibility of musculoskeletal injury by increasing connective tissue extensibility, which may improve joint range of motion and function, while possibly improving muscular performance. The ACSM also suggest that a warm up may have a preventative value at reducing the occurrence of various traumatic cardiovascular events. What must be pointed out however is that the word may is used often which means that these suggestions haven't been totally verified. What can be taken from the ACSM guidelines is that a warm up is prudent before physical activity for many reasons even though improvements in function and performance and the prevention of injury and dysfunction have not been confirmed through research.

This study will investigate the physiological effects of a particular warm-up modality; self myofascial releasing, compared to traditional stretching of the hamstring muscles of trained subjects. The hypothesis of this study is that muscular releasing is more effective than traditional stretching at improving strength, and jump performance. It is also hypothesized that this can be accomplished without negatively impacting measures of range of motion.

So how should a person properly warm up for physical activity? Even among exercise professionals and researchers the answer you get depends on whom you ask. This is an important topic in the health and fitness field considering that many people generally perform static stretching or other modalities before rehabilitation, fitness, and other athletic activities.

The practice of warming up prior to exercise is advocated in injury prevention programs, but this suggestion is based on limited clinical evidence. Researchers performed a systematic review of relevant warm-up studies. Three of the studies cited found that performing a warm-up prior to performance significantly reduced the injury risk, and the other two studies found that warming up was not effective in significantly reducing the number of injuries. Therefore the authors suggested that there is insufficient evidence to endorse or discontinue routine warm-up prior to physical activity to prevent injury among sports participants. However, the authors did suggest that the weight of evidence is in favor of a decreased risk of injury (Fradkin, 2006). As for the effect of a warm-up on performance there is also limited clinical evidence. A handful of studies have investigated various aspects of common warm-up practices. A study proposed that longer warm-up protocols are recommended in the morning to minimize the diurnal fluctuations of anaerobic performances (Soussi, 2010). Another study found that a warm-up prior to a vertical jump was shown to improve performance in collegiate football players. The study found posttest jump performance improved in all groups; however when static stretching was performed after the warm-up the benefits gained from the general warm-up were significantly lower. The negative effects of static stretching prior to performance were apparent throughout this article (Holt, 2008). Individual responses to any warm-up should be chief among a fitness professional's concerns, and the authors of a particular study emphasized that point. The authors stressed that the variation in responses to warm-up conditions in their study emphasizes the unique nature of individual reactions to different warm-ups; however, there was a tendency for warm-ups with an active component to have beneficial effects. The data suggests dynamic stretching has greater applicability to enhance performance on power outcomes compared to static stretching (Curry, 2009). An attempted explanation of the physiological mechanisms of an effective warm-up was offered in a particular study. The authors suggested that the most likely mechanisms to explain the increase in performance with a dynamic stretch treatment compared with the static stretch treatment are increased heart rate, greater muscle activity, and increased peak torque. (Fletcher, 2010). From a practical standpoint, there does not appear to be any evidence suggesting that a warm-up is somehow detrimental to physical performance. The authors of one study pointed out that despite their data not demonstrating a significant difference in time to exhaustion between a warm-up treatment and a control group, a warm-up might still be considered in events where the winning margin is often small (Wittekind, 2009). The only potential drawback is the opportunity cost of the time utilized warming-up, but the apparent benefits should outweigh any concerns over lost time in most performance scenarios. Of course, the most important consideration in any fitness method is the individual's response to that particular method.

Another study looked at golfer's participation in a warm up and its effects on injury. The authors suggested that few golfers perform an appropriate warm-up that may prevent injuries. Injuries in golf like many other sports occur at any age and ability and can significantly impact one's life. The survey involved a survey of 522 golfers, who reported their golf activities, injury status and warm-up habits over a 12-month period. About a third of the golfers (35.2 percent) reported an injury, most frequently to the lower back, shoulder or elbow. Strains were by far the most commonly reported type of injury (37.8 percent). Other types of injuries included stiffness, inflammation, tendonitis, and sprains and, less commonly, pinched nerves, fractures, heel spurs and contusions or dislocations. The authors suggested that only a small percentage of golfers were shown to perform an appropriate warm-up prior to play or practice. This low participation can possibly be suggested of many other sports. The authors indicated that golfers who reported not warming-up on a regular basis were more likely to have reported a golfing injury in the previous 12 months than those reporting consistent warm-up participation. The author suggested that a warm up should consist of three components:

1. Aerobic exercise to increase muscle temperature

2. Sport-specific stretching (including stretching the shoulder, trunk, chest, lower back, hamstrings, forearm, and wrist)

3. Activity similar to the event, starting slowly and building in intensity (For golf, this might consist of air swings involving the club but not the ball). These suggestions could

be structured and implemented for other sports as well. The study's authors suggest that only three percent of golfers surveyed regularly performed two or more of the components, leaving them vulnerable to injury. (Fradkin, 2007). This study is one of the few to establish an association between warm-up participation and injury. Another study confirmed these findings, stating that a basic review of golf swing biomechanics reveals significant torque stress on the shoulders, elbows, wrists, and lower back, which also corresponds to the most common areas of injury. The authors emphasized that understanding the underlying mechanism makes it possible to design a sport-specific injury prevention program (Brandon, 2009). Further prospective studies are warranted to determine whether warm-up reduces injury risk for golf participation. Considering the number of benefits and the ease of implementation, a general warm up is nearly universally suggested before sport or exercise participation. The next question is what type of warm-up modality is ideal before said exercise participation?

Most fitness related organizations like the American College of Sports Medicine (ACSM) suggest that an adequate range of motion be maintained in all joints for optimal musculoskeletal function(ACSM, 2006). Therefore the ACSM recommends flexibility promoting actvites such as static stretching in preventative and rehabilitative programs.

A lack of flexibility can be very serious. Aging is a slow decline in physiological function where reductions in flexibility typically occur and progress, and if left unchecked lead to decrements in activities of daily living and disability. Joints that don't have normal mobility may become arthritic in any population. Stretching is recommended by the ACSM for the elderly as well as other populations.

According to the ACSM, stretching is the systematic elongation of the musculotendinous units to create a persistent length of the muscle and a decrease in passive tension; the goal of which is to improved flexibility. Stretching has be shown to improve flexibility for the short term, but there is lack of evidence showing that it is any more than transient. Believing that stretching induced improvements are infact transient many experts recommend daily stretching. There are different forms of stretching techniques; static, proprioreceptive neuromuscular facilitation (PNF), and dynamic. Static stretching is recommended by the ACSM for the general population due to less chance of injury compared to the other techniques. Static stretches slowly lengthen the muscle to the end of range of motion to a point of no discomfort where it is held for 15 to 30 seconds. According to the ACSM improvements in flexibility from static stretches occur after 15 seconds where there is no significant improvement after 30 seconds, and 2 to 4 repetitions are recommended. A study confirmed this, finding that a duration of 30 seconds is an effective time of stretching for enhancing the flexibility of the hamstring muscles. In this particular study, stretch times longer than 30 seconds were utilized successfully but with no further improvements in flexibility compared to 30 second holds (Bandy, 1994). Another study did find that longer hold times during stretching of the hamstring muscles resulted in a greater rate of gains in ROM and a more sustained increase in ROM in elderly subjects. The authors went on to suggest these results may differ from those of studies performed with younger populations because of age-related physiologic changes (Feland, 2001).

There are other forms of stretching besides static; dynamic and ballistic are often used among athletes. According to the ACSM stretching that uses momentum created by repetitive bouncing movements to produce a stretch, where there is considerable tension and a fast onset of strain placed on the muscle, may put an individual at risk for muscle soreness and injury. Therefore the ACSM suggest the use of this type of stretching, which some call ballistic, should be used cautiously by athletes and not by other populations. The reason for the caution is that ballistic stretching uses the momentum of a moving body part in an attempt to force it beyond its normal range of motion where fast motions occur into and out of a stretched position making the muscle act like a spring (i.e. rapidly touching your toes repeatedly). These actions may not allow the musculature to adjust to and relax in the stretched position, it may also cause the stretch reflex to be repeatedly activated which may cause further tightening and the eccentric strain could cause tissue damage. Some confuse ballistic stretching with dynamic stretching. Dynamic stretching is similar to ballistic stretching except that it avoids bouncing motions and tends to incorporate more sport-specific movements. Dynamic stretching involves moving parts gradually increasing reach, speed of movement, or both such as, controlled leg swings, arm swings, or torso twists that take one to the limits of their range of motion but not beyond. In dynamic stretches there are no bounces or jerky, jarring movements. That being said a debate should be raised if dynamic strecthing motions, ballistic being one, which are considered by the ACSM to be a form of stretching are true stretching. The author suggested that dynamic motions can be considered more of a warm-up exercise than exercises designed to improve flexibility, which is what stretching is defined as.

There has been a considerable amount of research investigating the effects of stretching on strength and power, where there is some speculation that static stretching is detrimental to these measures. Researchers suggest that stretching may decrease muscular performance due to changes in the mechanical properties of the muscle, such as an altered length-tension relationship or a central nervous system inhibitory mechanism (Cramer, 2004). Another study suggests that relatively extensive static stretching decreases leg extension power performance compared to non-stretching (Yamguchi, 2006). An additional study by the same authors suggest that static stretching for 30 seconds neither improves nor reduces muscular power and that dynamic stretching enhances muscular power (Yamaguchi, 2005). Another study's findings indicated that prolonged stretching of a single muscle decreases voluntary strength for up to 1 hour after the stretch as a result of impaired activation and contractile force in the early phase of deficit and by impaired contractile force throughout the entire period of deficit (Fowles, 2000). Another study suggests that the negative impact of stretching activities on maximal torque production might be limited to movements performed at relatively slow velocities (Nelson, 2001). Based on the aforementioned studies, power may be affected by static stretching but it may be dependent on velocity of movement, while dynamic stretching may enhance dynamic performance. Given this information there is no clear answer to whether static stretching affects strength the same way in everyone or not.

Emerging research is beginning to surface in favor of moderate static stretching, if injury prevention is an assumed benefit and reasonable static stretch protocols are utilized with adequate rest time prior to performance. A study found that resistance-trained athletes can include either (a) a dynamic warm-up with no stretching or (b) a dynamic warm-up in concert with low- or high-volume static or PNF flexibility exercises before maximal upper body isotonic resistance-training lifts, if adequate rest is allowed before performance (Molacek, 2010). Another study published a year prior had similar findings with additional practical applications. Based on the findings of this study and the literature, the researchers suggested that trained individuals who wish to implement static stretching should include an adequate warm-up and dynamic sport-specific activities with at least 5 or more minutes of recovery before their sport activity. The study had also found static stretch to be the most beneficial when it was a point of discomfort was not attained (Chaouachi, 2009). Another study found that acute static stretching of the throwing shoulder does not have a significant impact on baseball pitching performance in terms of average velocity, maximum velocity, or accuracy measures. The authors go on to suggest that static stretching of the shoulder may be performed during a warm-up before a throwing activity (Haag, 2010). In contrast to the findings that static stretching may only affect low velocity movements, a study found that 20 meter repeated sprint ability may be compromised when static stretching is conducted after dynamic activities and immediately prior to performance (Sim, 2009). It is worth noting that the aforementioned study had subjects perform their tests immediately after their static stretching treatment. The emerging trend seems to indicate a minimal decrement in performance if adequate (5-10 minutes in most studies) rest time is allowed prior to performance.

Considering that static stretching may affect power production, researchers suggest it may affect maximal jumping performance, which is a key component of many athletic activities. The results of a study found that static stretching of the gastrocnemius muscles had a negative effect on maximal jumping performance. The authors point to the practical importance of this for coaches and athletes, who may want to consider the potential adverse effects of performing static stretching of the gastrocnemius muscles only before a jumping event, as jump height may be negatively affected (Wallmann, 2008). Another study investigating the effects of static, ballistic, and proprioceptive neuromuscular facilitation (PNF) stretching on vertical jump performance found a decrement on vertical jump performance for 15 minutes if performed after static or PNF stretching, whereas ballistic stretching has little effect on jumping performance. Consequently, the authors suggest PNF or static stretching should not be performed immediately prior to an explosive athletic movement (Bradley, 2007). A similar study found that 3 different warm-ups did not have a significant effect on vertical jumping. The warm-ups included a 600-m jog, a 600-m jog followed by a dynamic stretching routine, and a 600-m jog followed by a proprioceptive neuromuscular facilitation (PNF) routine. The results also showed there were no gender differences between the 3 different warm-ups (Christensen, 2008) .The impact of static stretching on vertical jump height might not be the same when comparing trained and untrained people. A study found no significant difference in vertical jump scores as a result of static or ballistic stretching in trained women (Unick, 2005). Even among trained individuals, responses to various stretching protocols may vary considerably among athletes, even those trained for the same sport. A study found that there were no significant statistical differences between a static stretch treatment, dynamic stretch treatment, and no stretch control group for any vertical jumps.

Despite the lack of significant effects for the group however, there were notable individual responses to each of the warm-up conditions. The authors suggested that practitioners should be aware of the individual responses of their athletes to different types of warm-up protocols before athletic performance and the possible impact of prescribing or eliminating certain exercises (Dalrymple, 2010). The aforementioned studies appear to suggest that maximal jumping performance is affected by static stretching but it may only affect the untrained and the effect is only short lived, while dynamic stretching may enhance maximal jumping performance.

Stretching is often included as part of a warm-up procedure before sport participation. However, as mentioned in the vertical jump studies the effectiveness of stretching with respect to sport performance has come into question. Another study compared ballistic stretching, static stretching, and sprinting on vertical jump performance. Only the ballistic stretching group demonstrated an acute increase in vertical jump 20 minutes after basketball play. The authors suggest coaches should consider using ballistic stretching as a warm-up for basketball play, as it is beneficial to vertical jump performance (Woolstenhume, 2006). A study of professional soccer players confirms the use of dynamic stretching, it showed that a dynamic-stretch protocol produced significantly faster agility performance than did both the no-stretch protocol and the static-stretch protocol. The authors concluded that static stretching did not appear to be detrimental to high-speed performance when included in a warm-up for professional soccer players. However, dynamic stretching during the warm-up was most effective as preparation for subsequent high-speed performance (Little, 2006). Another study using elite youth soccer players found that a dynamic warm-up with the inclusion of resistance enhances jumping ability more than dynamic exercise alone. In addition, a dynamic warm-up produces a superior sprint and jump performance compared to a warm-up consisting of static stretching (Needham, 2009). A study compared the effect of a dynamic warm up with a static-stretching warm up on selected measures of power and agility (T-shuttle run, underhand medicine ball throw for distance, and 5-step jump). The study revealed better performance scores after the dynamic warm up for all 3 performance tests, while static stretching showed better scores on the 5-step jump comparable to non-stretching. The authors suggest a relative performance enhancement with the dynamic warm up, and they ask for a reassessment of the utility of warm up routines that use static stretching as a stand-alone activity (McMillian, 2006). Another study found that static stretching does not appear to be detrimental to agility performance when combined with a dynamic warm-up for professional soccer players. However, dynamic stretching during the warm-up was most effective as preparation for agility performance. The data from this study suggest that more experienced players demonstrate better agility skills due to years of training and playing soccer (Khorasani, 2010). An additional study suggested that it may be desirable for soccer players to perform dynamic exercises before the performance of activities that require a high power output (Gelen, 2010). From the aforementioned studies it can be ascertained that sports performance was not generally affected by static stretching, while dynamic stretching appeared to enhance sport performance.

A study of running economy suggested that inflexible runners use less energy (i.e., are more economical) than flexible runners in covering a given distance at a given speed (Gleim, 1990, Nelson, 2001). The reasons for this are not exact, although the authors speculated that stiff runners may store and recycle more elastic energy from one stride to the next and/or may devote less energy to maintaining a stable upright posture while running. In contrast another study revealed no significant correlations between running economy and flexibility measures. Furthermore, results were in contrast to studies reporting positive relationships between flexibility and running economy, the aforementioned study included (Beaudoin, 2005). Another study found that an acute static stretching bout did not reduce time to exhaustion at a power output corresponding to VO2max, possibly by accelerating aerobic metabolism activation at the beginning of exercise. The authors suggest that coaches and practitioners involved with aerobic dependent activities may use static stretching as part of their warm-up routines without fear of diminishing high-intensity aerobic exercise performance (Samogin, 2010). An additional study indicated a significant relationship between sit-and-reach scores and running economy at an absolute velocity, as well as a significant sex difference in sit-and-reach scores. The significant relationship demonstrated that the less flexible distance runners tended to be more economical, possibly as a result of the energy-efficient function of the elastic components in the muscles and tendons during the stretch-shortening cycle (Trehearn, 2009). These inconsistent findings contradict the general assumption that more flexibility is always better. Range of motion requirements may be activity and even gender specific.

A common perception among the exercising public is that stretching will reduce the likelihood of an acute injury during a workout. However, there is conflicting evidence in regards to stretching and injury prevention. A study examined 1538 Australian army recruits randomly divided into stretch and control groups. The authors suggested a typical pre-exercise stretching protocol does not produce a clinically useful reduction in injury risk. Their best estimate of the effect of stretching is that is reduces all-injury risk by 5%, and we are able to rule out a 23% or greater reduction in injury risk with 95% certainty. They continue by suggesting that when these results are expressed in absolute terms, the futility of stretching becomes apparent. Recruits stretched for 40 sessions over the course of training, and so, on average, each recruit would need to stretch for 3100 physical training sessions to prevent one injury. As it took 5 min to complete the stretches, an average of 260 hours of stretching would be required to prevent one injury (Pope, 2000). A literature review on stretching and injury prevention found that there is moderate to strong evidence that routine application of static stretching does not reduce overall injury rates. There is preliminary evidence, however, that static stretching may reduce musculotendinous injuries (Small, 2008). The authors of another literature review concluded that due to the paucity, heterogeneity and poor quality of the available studies no definitive conclusions can be drawn as to the value of stretching for reducing the risk of exercise-related injury (Weldon, 2003). Other research has found that there is evidence that pre-participation stretching reduces the incidence of muscle strains but there is clearly a need for further work. Future prospective randomized studies should use stretching interventions that are effective at decreasing passive resistance to stretch and assess effects on subsequent injury incidence in sports with a high prevalence of muscle strains (McHugh, 2010). A lack of flexibility is generally associated with muscular injuries but some research has indicated poor range of motion in a particular muscle group could increase the likelihood of stress fractures as well. It has been stated that prevention of stress fractures is most effectively accomplished by increasing the level of exercise slowly, adequately warming up and stretching before exercise, and using cushioned insoles and appropriate footwear (Sanderlin, 2003). Further research is clearly needed to investigate the relationship between stretching and injury prevention. Unfortunately, it would be highly unethical to recreate injuries in a research setting, and further research on this topic may be relegated to meta-analyses and population studies. As a result, inconclusive evidence may continue to persist. As with other tenets of human performance, individual response may be the primary consideration in regards to stretching and injury prevention.

Although there are developing trends in the research, the question still remains as to what type of stretching should be performed? The answer could be based on whether the subject is an athlete or not, what type of activity will be performed, and what their goals are. If the goal is improved flexibility for rehabilitation purposes or due to tightness or muscle imbalance, static stretching seems to be better than or comparable to dynamic stretching (Bandy 1998). Dynamic stretching is useful before athletics competition and has been shown to reduce muscle tightness (Wityrouw, 2003). Muscle tightness is one factor associated with an increase occurrence of musculotendinous tears (Krivickas, 1996). The issue that needs to be raised with these studies is that even though static stretching effects strength and power the effects from it can be short lived and that some athletes may not be affected, and many athletes simply stretch to prevent injury. A review suggests that there is not sufficient evidence to endorse or discontinue routine stretching before or after exercise to prevent injury among competitive or recreational athletes. The authors suggest that further research, especially well-conducted randomized controlled trials, is urgently needed to determine the proper role of stretching in sports (Thacker, 2004).

The above discussion excludes some important points. The importance of attaining flexibility and training for flexibility varies considerably from sport to sport. What might be effective for a swimmer may not be good for a weight lifter. All athletic events require a certain range of motion about a joint and individuals who cannot comfortably achieve this range can benefit from stretching. Restoring normal joint mobility is a cornerstone of rehabilitation. Athletes with specific problems (such as muscle imbalances, chronic tightness, adhesions, or other injuries) should benefit from stretching. Stretching before and after activity might also signal an injury or altered tension that the athlete or fitness participant might not have been aware of.

While the literature on stretching is fairly extensive, there has been limited research investigating the effects of pre-exercise massage on performance (Weerapong, 2005). The studies that have been done have conflicted with one another. The Stick is a muscle massage device used by athletes, particularly track athletes, to improve performance. A study showed that use of the Stick had no effect on muscle strength, power, and flexibility (Mikesky, 2002). While manual massage to the forearm and hand after maximal exercise was associated with greater effects than non-massage on post-exercise grip performance (Brooks, 2005). One study, which goes against massage proponents suggestions found a reduction in knee extensor isokinetic force after massage treatment, which was suggested to be due to a change in architecture of the muscle fiber and not neuromuscular activity (Hunter, 2006). This could explain why massage administered prior to warm-up had no significant effect on subsequent 30-m sprint performance (Goodwin, 2007). In addition, another study found that massage as a pre-performance preparation strategy seems to decrease 20-m sprint performance when compared to a traditional warm-up, although its combination with a normal active warm-up seems to have no greater benefit then active warm-up alone. Therefore, massage use prior to competition is questionable because it appears to have no effective role in improving sprint performance (Fletcher, 2010). From the aforementioned studies, it can be observed that pre-competition or training massage has been found to have little efficacy in research.

Research on the value of massage as a method of recovery is more prevalent. Most investigations have provided little support for the use of massage to aid muscle recovery or performance after intense exercise. One study found this to be the case but the authors stated that further investigation using standardized protocols measuring similar outcome variables is necessary to more conclusively determine the efficacy of sport massage and the optimal strategy for its implementation to enhance recovery following intense exercise (Best, 2008). Another study implied that rest period duration exerts more influence on resistance exercise performance than massage and body part elevation, and that those who seek improved resistance exercise performance should pay particular attention to rest period durations. (Caruso, 2008). In contrast to these findings, another study concluded that subjecting muscle to compressive loads immediately after exercise leads to an enhanced recovery of muscle function and attenuation of the damaging effects of inflammation (Butterfield, 2008).

What fails to exist in the aforementioned studies however is a standardization of massage technique or administration . One study showed that the level of therapist training was shown to impact effectiveness of massage as a post-race recovery tool; greater reduction in muscle soreness was achieved by therapists with 950 hours of training as opposed to those with 700 or 450 hours (Moraska, 2007). This may explain why some studies have found massage to have no impact on recovery while others have found massage to be beneficial. Another study's authors attributed the inconsistent findings of massage studies on lack of control over various relevant factors such as exercise history and nutrition. The study found no measurable physiological effects of leg massage compared with passive recovery were observed on recovery from high intensity exercise, but the subsequent effect on a fatigue index warrants further investigation (Robertson, 2004). A favorable study for massage showed that myofascial release aids the recovery of heart rate variability and diastolic blood pressure after high-intensity exercise to pre-exercise levels (Arroyo-Morales, 2008). Another study indicated that massage resulted in a 10% to 20% decrease in the severity of soreness, but the differences between groups in the study were not significant. Difference in range of motion and arm circumference was not observed. The authors suggested that massage administered 30 minutes after exercises could have a beneficial influence on delayed onset muscle soreness (DOMS) but without influence on muscle swelling and range of motion (Bakowski, 2008). An additional study advocating massage as a recovery method found that massage was effective in alleviating DOMS by approximately 30% and reducing swelling, but it had no effects on muscle function (Zainuddin, 2005). More research needs to take place with experienced professionals using standardized technique to clarify the possible benefits of massage on performance.

Massage between events is widely investigated because it is believed that massage might help to enhance recovery and prepare athletes for the next event (Weerapong, 2005). Unfortunately, very little scientific data has supported this claim. Petrissage a form of massage is assumed to influence circulation as well as interstitial drainage of both superficial and deep tissues. One study found it to be effective at improving performance between bouts of consecutive bouts of supramaximal exercise performed by the lower leg muscles (Ogai, 2008). Post-exercise massage has been shown to reduce the severity of muscle soreness but massage has no effects on muscle functional loss (Hilbert, 2003).

There needs to be additional research into these areas considering the number of people who participate in fitness and athletic activities. One warm up activity and rehabilitation technique that seems to have a great deal of following is myofascial (muscular) releasing. Myofascial releasing is a therapeutic self-massage technique where body weight is applied to specific areas by rolling on a round foam roller or soft balls.

Self-myofascial release techniques have been suggested to improve flexibility, function, and performance and reduce the chance of injuries. After a search of the literature there seems to be no scientific research that has investigated the effects of self muscle releasing on range of motion, strength, power, and perceived function. Identifying a relationship between myofascial release and a battery of performance measures would help those utilizing the technique in the field establish a research base for their practical applications. It would also help add to the body of knowledge regarding warm-ups for physical activity, optimal preparation for athletic competition, and the effects of massage on human performance.

Methods

Participants:

In a repeated measures experimental design thirteen strength trained subjects will perform two training techniques to their hamstring musculature. Subjects will be selected based on accessibility for testing, the only other qualifying characteristic is at least 6 recent months of strength training. Subjects will be an assortment of personal trainers and clients from two separate personal training studios. The data collection will involve 3 meetings between subject and tester, spanning 3 to 4 weeks. Therefore, the subject's ability to participate in the testing on a somewhat rigid schedule without any planned conflicts will be an important consideration. Subjects will not be selected based on age or sex. Prior to participation subjects will be required to sign an informed consent form detailing the purpose of the study and their rights during the experimental process. A form will be submitted to the Institutional Review Board of Bridgewater State College for approval of research using human subjects. Once a group of thirteen subjects has been established and informed consent forms are signed and collected, the testing will begin.

A repeated measures design will have the subjects participating in both the control and treatments groups. Standard stretching and muscular releasing will be the training techniques. Subjects will be equally divided into 2 groups. Grouping is being employed to control for a training effect. Group one will perform standard stretching first and after 2 weeks or more of recovery subjects will perform muscular releasing to their right leg, while group two will perform muscular releasing first and standard stretching after 2 or more weeks of recovery.

Criterion measures will be recorded on the right leg on two separate occasions before treatments. This data will act as the control and be used to determine the reliability of the criterion measures.

Procedures:

Criterion Measures

1. Strength

Isometric strength of the knee flexors will be taken before and after the performance of each training technique. Subject's isometric knee flexor strength will be measured at the joint angle of 90 degrees in the prone position with test ankle flexed to 90 degrees. A cuff will be attached to the ankle. A chain will be attached to the cuff and to a dynamometer via a clip or hook. The chain will be kept parallel to the floor while the subject exerts a maximal isometric action by flexing the knee while the examiner is holding onto the dynamometer keeping chain parallel to floor. The thigh of the both legs must remain in contact with floor to avoid use of other muscles. Each isometric action will be held for 5 seconds followed by 1 minute recovery. Peak values will be recorded and the mean of the 3 trials will be taken as the criterion score.

2. Range of motion

Range of motion will be assessed using two protocols:

Supine range of motion of the hamstring muscle will be taken before and after the training technique. The subject will take a supine position, with the non-test leg against the floor. The tester will take the subject's leg into hip flexion while keeping the test leg's knee extended until the first resistance barrier and/or any spinal motion. The non-test leg will remain in contact with the floor and the test legs foot will be dorsiflexed to 90 degrees. No forced stretches will be made. The leg will only be taken to the point of first resistance barrier. At this point the perpendicular distance from the heel to the floor will be measured in millimeters and the distance will be recorded. The test leg must remain in its stretched position when measuring.

Seated range of motion of the hamstring muscle will be taken after the supine range of motion measure. Seated hamstring range of motion will be determined by having the subject seated in a figure 4 position with test leg straight with foot dorsiflexed to 90 degrees and non-test leg's foot's plantar aspect touching the medial knee aspect of test leg. The non-test leg is in a relaxed abducted position. The subject will reach as far forward with both hands until the first resistance barrier is met. No bouncing or forced stretch should be made. One hand will be placed on top of the other with palms facing down. The distance between index fingers and top of test foot will be recorded in millimeters where the top of test foot is considered zero and the distance reached before foot is recorded as a negative value and beyond as a positive value.

3. One leg jump

One leg jump performance measures will be taken before and after the training technique. Subjects will stand on one leg and will jump forward as far as they can. Subjects will be advised to land on both feet in order to avoid injury. The subjects will be allowed to squat down with test leg and to use both arms in the jumping motion. The non-test leg should be bent and will not be allowed to touch the ground until landing. Distance in millimeters will be recorded as the starting point to the heel of test foot at landing. Three trials will be followed by a 1 minute recovery. Peak values will be recorded and the mean of the 3 trials will be taken as the criterion score.

The training techniques

Stretching

Stretching treatment will resemble seated range of motion criterion measure. Subject will be seated in a figure 4 position with test leg straight with foot dorsiflexed to 90 degrees and non-test leg's foot's plantar aspect touching the medial knee aspect of test leg. The non-test leg is in a relaxed abducted position. The subject will reach as far forward with both hands until the first resistance barrier is met. No bouncing or forced stretch should be made. One hand will be placed on top of the other with palms facing down. When full resistance barrier is met the stretch should be held for 30 seconds. Thereafter the subject should rest for 10 seconds and the technique is repeated two more times. The ROM criterion measure will be taken immediately after stretching. After ROM measures strength measures will be assessed. After measuring strength the subject will perform the one leg jump test. After one leg jump measures are recorded stretching treatment and subsequent testing will be completed.

Self-Muscular releasing on the floor

The subject will sit down on the floor placing a 6 inch foam roller underneath their hamstrings perpendicular to the body, closer to the back of the knee. The upper body of the subject should make close to a 90 degree angle with the lower body. The leg of the test leg should be extended and the foot should be dorsiflexed to 90 degrees pointing straight upwards. The non-test leg should be bent where the foot is flat on the floor. The subject should place their hands beside their hips behind the roller and they should push up elevating their body from the floor slightly shifting to the side of the test leg. This places pressure on the test leg's hamstring. While muscular releasing the subject should bend forward from the waist until the first resistance barrier. When first resistance barrier is met the subject should roll along the roller so that he or she moves on top of the roller, from knee (hamstring insertion) to buttock (hamstring origin), and then the motion is reversed from buttock to knee. The subject's full weight should be applied to the roller. This forward and backward motion theoretically creates a releasing effect. Each motion will be done to a 3 count where 15 back and forth motions should be made which should take roughly 90 seconds. This treatment should not exceed 90 seconds. The ROM criterion measure will be taken immediately after releasing. ROM will be recorded after range of motion measures. After taking ROM measures strength will be assessed. After measuring strength the subject will perform the one leg jump test. After one leg jump measures are recorded muscular releasing treatment and subsequent testing will be completed.

Statistical Analysis

Criterion measures will be analyzed by determining the difference between baseline and treatment measures for the groups (releasing and stretching), followed by a t test to determine any significant changes between the two treatments. To determine the reliability of range of motion, isometric strength, and one leg jump, baseline values will be recorded on two days. The criterion for statistical significance was set at $p \leq 0.05$.

Results

Range of motion

No significant changes were found between SMR and SS for either ROM measure. For the prone ROM measure, the difference between the baseline and treatment for SMR was a mean of 7.2 centimeters with a standard deviation of 5.4. The difference between the baseline and treatment for SS was a mean of 3.6 with a standard deviation of 8.96. For the figure-4 ROM measure, the difference between the baseline and treatment for SMR was a mean of 4.47 with a standard deviation of 3.15. The difference between the baseline and treatment for SMR was a mean of 5.18 with a standard deviation of 4.26. Neither of these differences between treatments reached significance. A T-test for the prone ROM measure yielded 1.24, compared to a 2.064 needed to identify a significant difference. A t-test for the figure 4 ROM measure yielded -.48, compared to a 2.064 needed to identify a significant difference. In summary, no significant differences were found between SMR and SS in the two ROM measures of the hamstring musculature.

Strength

A significant difference was found in isometric strength measures when SMR was compared to SS. The difference between the baseline and treatment for SMR was a mean of 2.81 with a standard deviation of 3.7. The difference between the baseline and treatment for SS was a -.46 with a standard deviation of 2.16. The difference between these two reached significance. A t-test for the strength measure yielded 2.76, exceeding the 2.064 needed to identify a significant difference. In summary, a significant difference existed between SMR and SS in the strength measure of the hamstring musculature.

<u>One leg jump</u>

A significant difference was found in one leg jump measures when SMR was compared to SS. The difference between the baseline and treatment for SMR was a mean of 9.26 with a standard deviation of 15.41. The difference between the baseline and treatment for SS was a mean of -.23 with a standard deviation of 12.95. The difference between these two reached significance. A t-test for the one leg jump measure yielded 4.07, exceeding the 2.064 needed to identify a significant difference. In summary, a significant difference existed between SMR and SS in the one leg jump measure of the hamstring musculature.

Comparison of differences

ROM Prone

Subject	Release	Baseline 1	Dif	Sub	Stretch	Baseline 2	Dif
A	110	112	-2	A	114	106	8
B	108	101	7	B	111	108	3
C	107	86	21	C	92	109	-17
D	106	98	8	D	101	103	-2
E	99	97	2	E	101	100	1
F	103	96.5	6.5	F	99	97.5	2.5
G	106.5	96.5	10	G	96.5	94	2.5
H	101.5	95.5	6	H	95.25	96.25	-1
I	81	73.6	7.4	I	86	73.6	12.4
J	85	73.6	11.4	J	94	73	21
K	81	76.2	4.8	K	86	75	11
L	87.5	81	6.5	L	86	80	6
M	86	81	5	M	91	91.5	-0.5

			Mean					Mean
			7.2					3.6
			SD 5.4					SD 8.96

endpoints -2.367 < u1-u2 < 9.567
t test: 1.24 < 2.064 Not significant

ROM fig 4

Subjects	Release	Baseline1	Dif	Sub	Stretch	Base2	Dif
A	8	7	1	A	12	2	10
B	6	0	6	B	11	0	11
C	2	0	0	C	3	0	3
D	-11	-15	4	D	-14	-14	0
E	-12	-15	3	E	-11	-17	6
F	-21.5	-25.4	3.9	F	-25.4	-27	1.6
G	-10	-12.7	2.7	G	-12.7	-15.2	2.5
H	-7.5	-12.7	5.2	H	-10	-12.7	2.7
I	2.54	-9	11.54	I	2.54	-11.5	14.04
J	4	-3.8	7.8	J	2	-4	6
K	-3.8	-11.5	7.7	K	-7.6	-12.5	5.1
L	-10	-12.9	2.9	L	-6.5	-11.5	5
M	-7.6	-10	2.4	M	-7.6	-8	0.4
							Mean 5.18
			Mean 4.47				
			SD 3.15				SD 4.26

endpoints -3.737 < u1-u2 < 2.32
t test: -.48 < 2.064 Not significant

Strength

Subjects	release	base1	Dif	Sub	Stretch	base2	Dif
A	11	9	2	A	8	13	-5
B	9	8	1	B	9	5	4
C	13	15	-2	C	13	13	0
D	6	5	1	D	2	4	-2
E	6	6	0	E	6	7	-1
F	22	9.5	12.5	F	9.5	9.5	0
G	15	14	1	G	13	13.5	-0.5
H	7.5	3.5	4	H	2.5	3.5	-1
I	12	4.5	7.5	I	5.5	4.5	1

J	10.5	8	2.5	J	5.5	7.5	-2
K	14	10	4	K	8	10	2
L	12	11	1	L	10	11.5	-1.5
M	8	6	2	M	5	5	0
			Mean 2.81 SD 3.7				Mean -.46 SD 2.16

Endpoints 1.61 < U1-U2 <4.93
t test: 2.76 > 2.064
Significant

Jump

Subjects	release	base1	Dif	Subjects	Stretch	base2	dif
A	149	171	-22	A	175	136	39
B	128	142	-14	B	138	141	-3
C	139	138	1	C	150	146	4
D	109	75	34	D	99	108	-9
E	137	119	18	E	129	126	3
F	134	111.5	22.5	F	101.5	112.5	-11
G	119.5	112	7.5	G	113	114.5	-1.5
H	113.5	99	14.5	H	103	101.5	1.5
I	104	103	1	I	92	96.5	-4.5
J	113	87.6	25.4	J	101.5	106.5	-5
K	129	122	7	K	106	118	-12
L	129.5	119	10.5	L	110.5	118	-7.5
M	91	76	15	M	88	85	3
			Mean 9.26 SD 15.41				Mean -.23 SD 12.95

Endpoints -2.03 < U1-U2 < 21
t test: 4.07 > 2.064
Significant

Discussion

The purpose of this investigation was to provide insight into the tangible value for self myofascial releasing rollers, especially compared to static stretching. While there is growing anecdotal evidence of self myofascial release's efficacy, to date there are no formal studies that have been performed to measure it's effects. Generally speaking, the value of a pre-exercise warm-up is not questioned. If for no other reason, the perceived feelings of well being and improved physical capacity make warming up before any physical activity a helpful endeavor. In terms of human performance however, practicality and efficacy take precedence. Doing something simply because it "feels good" is not enough of an incentive for a high level athlete and his or her strength and conditioning. Quantifiable evidence needs to exist that the method being utilized is effective. This is where this particular study and ultimately further research should help shed light on the value of SMR.

ROM was greater in both SS and SMR treatments when compared to the control, where there was no difference between conditions. SS is generally a recommended method for increasing ROM as it has been found to be effective, safe, and easy to implement. In light of the findings of this study, SMR may be used in addition to or in replacement of SS. The increase in ROM from SMR may be due to the focal lengthening that the musculature experiences when the roller is contacting the muscle while under body weight pressure. A stretch also occurs to the hamstring and gluteal musculature from body positioning while performing releasing to the hamstring musculature.

SMR was shown to increase static strength of the hamstring musculature. This is the first study to show this effect. Research investigating massage has thus far been inconclusive at affecting strength. SMR producing an increase in strength may be due to a warm up effect of the musculature that massage does not offer. SMR of the hamstring musculature requires the arms to prop up the upper body and move the extended leg along the roller with the aid of the opposite leg, such an action requires an increase in total body metabolism. Studies have shown that a warm up activity which raises metabolism, like dynamic stretching, tends to in increase strength. SS was shown not to affect strength. This is interesting considering that some studies show a strength loss with SS. This study used recreationally weight trained subjects. Subjects in studies that were trained did not generally show a strength loss after SS. The results presented confirm the results of these SS studies.

JUMP was increased with SMR compared to the control as well. Significance was reached despite the investigators suspicion that one subject may have been attempting to corrupt the data with an awareness of the hypothesis for personal reasons. Had this subject been omitted from the data, the data would have shown even greater significance. The increase in jump performance may be attributed to the same mechanisms suggested for the increase in strength. This improvement with SMR compared to SS suggests that the improvements sought after with a warm-up are not limited to isometric strength but unilateral power as well.

Given the results of this study, SMR should be considered as a valuable tool for preparing a competitive or recreational athlete for exercise. Based on the data collected, it appears SMR offers increased strength and jumping ability, without any difference in transient ROM improvements that SS is perceived to offer. The method can be implemented immediately preceding any type of resistance, plyometric, or speed training session. Based on the current research, a combination of myofascial release, dynamic stretching, and specific low load muscle activation could be an ideal warm-up protocol for any type of workout. Given the obvious narrow scope of this study, focusing exclusively on the hamstring musculature, it may be premature to anoint SMR as an appropriate and effective technique for any and all athletes. More research is needed using alternative protocols, different fitness tests, and alternative muscle groups. However, with mounting anecdotal evidence in favor of SMR and now a small amount of research demonstrating efficacy, fitness professionals would be well served to familiarize themselves with various SMR techniques.

References

American College of Sports Medicine. (2006). *Acsm's guidelines for exercise testing and prescription*. Baltimore, MD: Lippincott, Williams and Wilkins.

Arroyo-Morales, M, Olea N, Martinez, M, Moreno-Lorenzo, C, Díaz-Rodríguez, L, Hidalgo-Lozano, A. (2008) Effects of myofascial release after high-intensity exercise: a randomized clinical trial. *Journal of Manipulative Physiological Therapy,* 31, 217-223.

Bakowski, P, Musielak, B, Sip, P, & Bieganski, G. (2008). Effects of massage on delayed-onset muscle soreness. *Chirurgia narzadów ruchu i ortopedia polska*, *73*(4), 261-5.

Bandy, WD, & Irion, JM. (1994). The Effect of time on static stretch on the flexibility of the hamstring muscles.. *Physical Therapy*, *74*(9), 850-2.

Bandy, WD, Irion, JM, & Briggler, M. (1998). The Effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. . *The Journal of Orthopaedic and Sports Physical Therapy*, *27*(4), 295-300.

Best, TM, Hunter, R, Wilcox, A, Haq, F. (2008) Effectiveness of sports massage for recovery of skeletal muscle from strenuous exercise. *Clinical Journal of Sports Medicine,* 18, 446-460.

Bradley, PS, Olsen, PD, Portas, MD. (2007) The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *Journal of Strength and Conditioning Res*earch, 21, 223-226.

Brandon, B, & Pearce, PZ. (2009). Training to prevent golf injury. *Current Sports Medicine Reports*, *8*(3), 142-6

Brooks, CP, Woodruff, LD, Wright, LL, Donatelli, R. (2005) The immediate effects of manual massage on power-grip performance after maximal exercise in healthy adults. *Journal of Alternative and Complemenaryt Medicine,* 11, 1093-1101.

Butterfield, TA, Zhao, Y, Agarwal, S, Haq, F, & Best, TM. (2008). Cyclic compressive loading facilitates recovery after eccentric exercise.. *Medicine and Science in Sports and Exercise*, *40*(7), 1289-96.

Caruso, JF, Coday, MA. (2008) The combined acute effects of massage, rest periods, and body part elevation on resistance exercise performance. *Journal of Strength and Conditoning Res*earch, 22, 575-582.

Chaouachi, A, Castagna, C, Chtara, M, Brughelli, M, & Turki, O. (2009). Effect of warm-ups involving static or dynamic stretching on agility, sprinting, and jumping performance in trained individuals. *Journal of Strength and Conditioning Research*. Retrieved from http://www.ncbi.nlm.nih.gov/sites/pubmed.

Christensen BK, Nordstrom BJ. (2008) The effects of proprioceptive neuromuscular facilitation and dynamic stretching techniques on vertical jump performance. *Journal of Strength and Conditioning Research,* 22(6), 1826-31.

Craib, MW, Mitchell, VA, Fields, KB, Cooper, TR, Hopewell, R, Morgan, DW. (1996) The association between flexibility and running economy in sub-elite male distance runners. *Medicine and Science in Sports and Exerc*ise, 28, 737-743.

Cramer, JT, Housh, TJ, Johnson, GO, Miller, JM, Coburn, JW, Beck, TW. (2004). Acute effects of static stretching on peak torque in women. *Journal of Strength and Conditioning Research*, 18, 236-241.

Curry, BS, Chengkalath, D, Crouch, GJ, Romance, M, & Manns , PJ. (2009). Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women. *Journal of Strength and Conditioning Research*, *23*(6), 1811-9.

Dalrymple, KJ, Davis, SE, Dwyer, GB, & Moir, GL. (2010). Effect of static and dynamic stretching on vertical jump performance in collegiate women volleyball players. *Journal of Strength and Conditioning Research*, *24*(1), 149-55.

Feland, JB, Myrer, JW, Sculthies, SS, Fellingham, GW, & Measom, GW. (2001). The Effect of duration of stretching of the hamstring muscle group for increasing range of motion in people aged 65 years or older.. *Physical Therapy*, *81*(5), 1110-7.

Fletcher , IM. (2010). The Effects of precompetition massage on the kinematic parameters of 20-m sprint performance. *Journal of Strength and Conditioning Research*, *24*(5), 1179-83.

Fletcher, IM, & Monte-Columbo, MM. (2010). An Investigation into the possible physiological mechanisms associated with changes in performance related to acute responses to different preactivity stretch modalities.. *Applied Physiology, Nutrition, and Metabolism*, *35*(1), 27-34.

Fowles, JR, Sale, DG, & MacDougall, JD. (2000). Reduced strength after passive stretch of the human plantarflexors.. *Journal of Applied Physiology*, *89*(3), 1179-88.

Fradkin AJ, Gabbe BJ, Cameron PA. (2006). Does warming up prevent injury in sport? The evidence from randomized controlled trials. *Journal of Science and Medicine in Sport,* 9(3), 214-20.

Fradkin AJ, Cameron PA, Gabbe BJ. (2007) Is there an association between self-reported warm-up behavior and golf related injury in female golfers? *Journal of Science and Medicine in Sport*, 10(1), 66-71.

Gelen, E. (2010). Acute effects of different warm-up methods on sprint, slalom dribbling, and penalty kick performance in soccer players. *Journal of Strength and Conditioning Research*, *24*(4), 950-6.

Gleim, GW, Stachenfeld, NS, Nicholas, JA. (1990) The influence of flexibility on the economy of walking and jogging. *Journal of Orthopaedic Research*, 8, 814-823.

Goodwin, JE, Glaister, M, Howatson, G, Lockey, RA, McInnes, G. (2007) Effect of pre-performance lower-limb massage on thirty-meter sprint running. *Journal of Strength and Conditioning Res*earch, 21, 1028-1031.

Haag, SJ, Wright, GA, Gillette, CM, & Greany, JF. (2010). Effects of acute static stretching of the throwing shoulder on pitching performance of national collegiate athletic association division III baseball players. *Journal of Strength and Conditioning Research*, *24*(2), 452-7.

Hilbert, JE, Sforzo, GA, Swensen, T. (2003) The effects of massage on delayed onset muscle soreness. *British Journal of Sports Med*icine, 37, 72-75.

Holt BW, Lambourne K. (2008) The impact of different warm-up protocols on vertical jump performance in male collegiate athletes. *Journal of Strength and Conditioning Research,* 22(1), 13-9.

Hunter, AM, Watt, JM, Watt, V, Galloway, SD. (2006) Effect of lower limb massage on electromyography and force production of the knee extensors. *British Journal of Sports Medicine,* 40, 114-118.

Khorasani MA, Sahebozamani M, Tabrizi KG, Yusof AB. (2010) Acute Effect of Different Stretching Methods on Illinois Agility Test in Soccer Players. *J Strength Cond Res*. Retrieved from http://www.ncbi.nlm.nih.gov/sites/pubmed

Krivickas, L.S., Feinberg, J.H. (1996) Lower extremity injuries in college athletes: relation between ligamentous laxity and lower extremity muscle tightness. *Archives of Physical Medicine and Rehabilitation,* 77(11), 1139-43.

Little, T, Williams, AG. (2006) Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *Journal of Strength and Conditioning Research*, 20, 203-207.

McHugh, MP, & Cosgrave, CH. (2010). To Stretch or not to stretch: the role of stretching in injury prevention and performance. *Scandinavian Journal of Medicine and Science in Sports*, *20*(2), 169-81.

McMillian, DJ, Moore, JH, Hatler, BS, Taylor, DC. (2006) Dynamic vs. static-stretching warm up: the effect on power and agility performance. *Journal of Strength and Conditioning Res*earch, 20, 492-499.

Mikesky, AE, Bahamonde, RE, Stanton, K, Alvey, T, Fitton, T. (2002) Acute effects of The Stick on strength, power, and flexibility. *Journal of Strength and Conditioning Research*, 16, 446-450.

Molacek, ZD, Conley, DS, Evetovich, TK, & Hinnerichs, KR. (2010). Effects of low- and high-volume stretching on bench press performance in collegiate football players. *Journal of Strength and Conditioning Research*, *24*(3), 711-6.

Moraska, A. (2007) Therapist education impacts the massage effect on postrace muscle recovery. *Medicine and Science in Sports and Exercise* 39, 34-37.

Needham, RA, Morse, CI, & , Initials. (2009). The Acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. *Journal of Strength and Conditioning Research*, *23*(9), 2614-20.

Nelson, A.G., Guillory, I. K., Cornwell, A., & Kokkonen, J. (2001) Inhibition of Maximal Voluntary Isokinetic Torque Production Following Stretching Is Velocity-Specific. *Journal of Strength and Conditioning Res*earch, 15, 241-246.

Ogai, R, Yamane, M, Matsumoto, T, Kosaka, M. (2008) Effects of petrissage massage on fatigue and exercise performance following intensive cycle pedalling. *British Journal of Sports Med*icine, 42, 534-538.

Pope, RP, Herbert, RD, Kirwan, JD, Graham, BJ. (2000) A randomized trial of preexercise stretching for prevention of lower-limb injury. *Medicine and Science in Sports and Exerc*ise, 32, 271-277.

Robertson, A, Watt, JM, & Galloway, SD. (2004). Effects of leg massage on recovery from high intensity cycling exercise.. *British Journal of Sports Medicine*, *38*(2), 173-6.

Samogin Lopes, FA, Mengon, EM, Franchini, E, Tricoli, V, & de M Bertuzzi, RC. (2010). Is Acute static stretching able to reduce the time to exhaustion at power output corresponding to maximal oxygen uptake? *Journal of Strength and Conditioning Research*, *24*(6): 1650-6.

Sanderlin, BW, & Raspa, RF. (2003). Common stress fractures. *American Family Physician*, *68*(8), 1527-32.

Sim, AY, Dawson, BT, Guelfi, KJ, Wallman, KE, & Young , WB. (2009). Effects of static stretching in warm-up on repeated sprint performance. *Journal of Strength and Conditioning Research*, *23*(7): 2155-62.

Small K, Mc Naughton L, Matthews M. (2008) A systematic review into the efficacy of static stretching as part of a warm-up for the prevention of exercise-related injury. *Research in Sports Medicine,* 16(3): 213-31.

Soussi, N, Driss, T, Chamari, K, Vandewalle, H, & Davenne, D. (2010). Diurnal variation in wingate test performances: influence of active warm-up. *Chronobiology International*, *27*(3): 640-52.

Thacker SB., Gilchrist J, Stroup DF, Kimsey CD. (2004) The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature. *Medicine and Science in Sports and Exercise*, 36(3): 371-378

Trehearn TL, Buresh RJ. (2009) Sit-and-reach flexibility and running economy of men and women collegiate distance runners. *Journal of Strength and Conditioning Research,* 23(1): 158-62.

Unick, J, Kieffer, HS, Cheesman, W, Feeney, A. (2005) The acute effects of static and ballistic stretching on vertical jump performance in trained women. *Journal of Strength and Conditioning Res*earch, 19: 206-212.

Wallmann, HW, Mercer, JA, Landers, MR. (2008) Surface electromyographic assessment of the effect of dynamic activity and dynamic activity with static stretching of the gastrocnemius on vertical jump performance. *Journal of Strength and Conditioning Research*, 22: 787-793.

Weerapong, P, Hume, PA, Kolt, GS. (2005) The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sports Medicine*, 35: 235-256.

Weldon, SM, & Hill , RH. (2003). The Efficacy of stretching for prevention of exercise-related injury: a systematic review of the literature.. *Manual Therapy*, *8*(3), 141-50.

Wittekind, AL, & Beneke, R. (2009). Effect of warm-up on run time to exhaustion. *Journal of Science and Medicine in Sport*, *12*(4): 480-4.

Witvrouw, E., Danneels, L., Asselman, P., D'Have, T., Cambier, D. (2003) Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. *American Journal of Sports Medicine*, 31(1): 41-6.

Woolstenhulme, MT, Griffiths, CM, Woolstenhulme, EM, Parcell, AC. (2006) Ballistic stretching increases flexibility and acute vertical jump height when combined with basketball activity. *Journal of Strength and Conditioning Research,* 20: 799-803.

Yamaguchi, T, Ishii, K. (2005) Effects of Static Stretching for 30 Seconds and Dynamic Stretching on Leg Extension Power. *Journal of Strength and Conditioning Research*, 19: 677-683.

Yamaguchi, T, Ishii, K, Yamanaka, M, Yasuda, K. (2006) Acute effect of static stretching on power output during concentric dynamic constant external resistance leg extension. *Journal of Strength and Conditioning Research*, 20: 804-810.

Zainuddin, Z, Newton, M, Sacco, P, & Nosaka, K. (2005). Effects of massage on delayed-onset muscle soreness, swelling, and recovery of muscle function.. *Journal of Athletic Training*, *40*(3), 174-80.