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Effect of Vibration Foam Rolling and Non-Vibration Foam Rolling in the Lower Extremities on Jump Height

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EFFECTS OF VIBRATION FOAM ROLLING AND NON-VIBRATION FOAM ROLLING IN THE LOWER EXTREMITIES ON JUMP HEIGHT

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Abstract

The objective of this study was to investigate whether a vibration stimulus combined with foam rolling yields better power output in the lower extremities during a countermovement jump (CMJ), than a group who uses foam rolling without vibration compared to no warm-up. Eighteen female and male participants, EWU athletes volunteered for this study but three were unable to complete all testing. The design was a randomized cross-over design so all participants served as their own control by participating in all three interventions which consist of; (a) no-warm-up, (b) non-vibration foam rolling (FRNV), and (c) vibration foam rolling (FRV). Post-intervention measurements were compared for differences in anaerobic power assessed by a jump reach test using the Vertc. Each foam rolling session lasted six minutes on each leg with 90 seconds per muscle group. The muscles were foam rolled in a specific order starting with the hamstring, quadriceps gastrocnemius, and soleus. Three countermovement jumps (CMJ) were conducted to achieve maximal height. The highest max CMJ jump was used for data collection. Participants were tested with one day between sessions at the same time each day. A repeated measures ANOVA was calculated to compare the mean scores of no warm-up jump mean to FRNV and FRV jump height scores. No significant effect was found ($F(2,28) = .669$, $p > .05$) with all subjects included. Though the Shapiro Wilks test indicated a normal distribution, the population was small and the box plots showed three outliers. A second repeated measures ANOVA was then run with outliers removed to determine if significance would occur without extreme scores present, but the results were still non-significant ($F(2,22) = 2.152$, $p > .05$). In conclusion, the present study indicated that performing one and a half minutes of FRNV, FRV compared to no warm-up had a non-significant effect on jump height.

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Chapter 1

Introduction

There is consensus that warm-up is essential for optimum performance in all athletic competition (Pagaduan, Pojskic, Uzicanin, & Babajic, 2012). While there are many forms of warm-up, they share a common goal of increasing muscle temperature. This causes increased elasticity of the muscles, improves muscle dynamics, and prepares the athlete for the demands of the exercise (Woods, Bishop, & Jones, 2007). In addition, the warm-up should produce a mild sweat without fatiguing the individual (Woods et al., 2007). Warm-up can be either passive or active (Bishop, 2000). A passive warm-up is one in which muscle temperature or core body temperature is increased by external means (Woods et al., 2007). This can include, hot showers, saunas, or heating pads, while the active warm-up involves some type of physical activity (Safran, Seaber, & Garrett, 1989; Shellock & Prentice, 1985; Woods et al., 2007).

An active warm-up can be classified as either general or specific (Woods et al., 2007). A general active warm-up involves any non-specific body movements such as jogging, cycling, or calisthenics; while a specific warm-up utilizes activities and stretches that are specific to the sport for which one is preparing (Safran et al., 1989; Shellock et al., 1985). In addition, stretches used in active warm-ups are incorporated into many sports or activities that require specifics in optimizing range of motion (ROM) or enhancing overall performance. These stretches include dynamic active stretching, proprioceptive neuromuscular facilitation (PNF) stretching, and passive stretching. (Chaouachi et al., 2009; Fletcher & Jones, 2004; Knusdon, Bennett, Corn, Leick, & Smith, 2001; Samson, Button, Chaouachi, & Behm, 2012; Vetter, 2007).

However, authors of previous reviews suggest that pre-exercise stretching such as those mentioned above may compromise a muscle’s ability to produce force (Behm, Button, & Butt, 2001; Cramer et al., 2004; Evetovich, Nauman, Conley, & Todd, 2003; Fowles, Sale, &

MacDougall, 2000; Kokkonen, Nelson, & Cornwell, 1998; McNeal & Sands, 2003; Nelson, Guillory, Cornwell, & Kokkonen, 2001; Shrier, 2004; Thacker, Gilchrist, Stroup, & Kimsey, 2004; Young & Elliott, 2001). Researchers have hypothesized that static and PNF stretching causes a decrease in musculotendinous stiffness in the muscle tendon unit (MTU) (Church, Wiggins, Moode, & Crist, 2001; Young & Behm, 2003). This suggests that these forms of stretching could impair force production in muscles as a result of changes in the force velocity and length-tension relationship (Fowles et al., 2000; Magnusson, 1998; McNeal et al., 2003; Nelson et al., 2001; Young et al., 2001). Another theory proposed that a decrease in power is related to the myogenic reflex (stretch reflex), which refers to a reduction of a natural contraction when muscles go through a range of motion very quickly (Church et al., 2001).

Recent research on acute effects of static stretching has addressed many of these controversial theories involving pre-competition stretching on performance variables (Kokkonen et al., 1998; Nelson & Kokkonen, 2005; Unick, Kieffer, Cheesman, & Feeney, 2005). Since the early 1980s, pre-activity static stretching had been widely promoted as a method to prevent injury and improve physical performance (Shrier & Gossal, 2000). While injury prevention is still controversial, static stretching has been shown to significantly reduce leg strength and high speed motor capabilities such as power and vertical jump (Behm & Kibele, 2007; Nelson et al., 2005). It has been shown that static stretching for 20 seconds with 10 second rest intervals can negatively affect specific lower limb performance tests (Arazi, Asadi, & Hoseini, 2012). The current consensus is static stretching for 20 seconds is not recommended for warm-ups prior to a power event (Arazi et al., 2012). Results from this study demonstrate that the longstanding belief that a more flexible muscle will produce better performances in anaerobic activity should be re-evaluated.

Pre-event massage has also been used as an adjunct to physical warm-up (Tessier & Draper, 2005). It has been shown that massage therapy is mainly used in major sporting events for preparation before competition and recovery from events by treating specific problems such as muscle spasms, scar tissue, or soft tissue adhesions (Galloway, Watt, & Sharp, 2004). A variety of massage techniques have been used including effleurage, petrissage, friction, and tapotement (Weerapong, Hume, & Kolt, 2005). These types of massage techniques commonly known as myofascial release (MFR) often are used to aid in easing fascial restrictions that occur in response to injury, disease, inactivity, or inflammation. As a result of these conditions, fascial tissue loses elasticity and becomes dehydrated (MacDonald et al., 2013) and massage can relieve them.

A study investigating the acute effects of pre-event lower limb massage on explosive and high speed motor capacities and flexibility; the authors found similar results to stretching indicating that 10 minutes of posterior and five minutes of anterior lower limb Swedish massage after a warm-up session significantly degraded performance in three measures of power: vertical jump, 10 meter acceleration, and 30 meter sprint. However an improvement was shown in the sit and reach test (Arabaci, 2008). This is in contrast to a study investigating the acute effects of petrissage and tapotement on ankle joint flexibility and power of the plantar flexors. This study showed that three minutes of massage increased ROM in the plantar flexor muscles with no detrimental effect on subsequent jumping power (McKechnie, Young, & Behm, 2007). The differences in this study may have been due to the number of different types of massage performed on specific muscle groups (one versus five) or the specific muscles chosen for experiment (plantar flexors versus hamstrings and quadriceps).

A new technique of MFR termed self-induced myofascial release (SMR) using rollers has been practiced widely throughout sporting circles and has become an increasingly common practice for treating soft-tissue restrictions (MacDonald et al., 2013). The difference between the two techniques is that instead of a therapist providing manual therapy to the soft tissue, an individual uses their own body weight on a foam roller to exert pressure on the soft tissue (MacDonald et al., 2013). Conversely, the effects of manual massage therapy and SMR via foam rolling are not in agreement on power performance.

A study investigating the acute effects of SMR on the ROM, maximal voluntary force, muscle activation of the quadriceps, tetanic force, twitch force, relaxation time, and rate force of development (RFD) (MacDonald et al., 2013), found a significant increase in knee joint ROM at two min post (12.7%) and 10 min post foam rolling (10.3%) of the quadriceps muscles. In addition, this study also found no significant changes in voluntary or evoked muscle properties following foam rolling. Furthermore, the results of this study demonstrate that an acute bout of foam rolling greatly improves joint ROM with no concomitant detrimental effects on neuromuscular force production, and no significant difference in RFD or muscle activation (MacDonald et al., 2013). Although SMR and manual massage therapy techniques are in agreement on increasing ROM, the difference in power might suggest that SMR may only have a positive effect on joint ROM a neutral effect on subsequent muscular force production when used for a short duration (Sullivan, Silvey, Button, & Behm, 2013).

Lastly, apart from different types of stretching and SMR, the application of vibration to an active muscle has been shown to cause a shift in electromyography (EMG) patterns (Issurin, Liebermann, & Tenenbaum, 1994). Vibration has also been shown to stimulate transient increases in certain hormones, such as growth hormone (Bosco et al., 2000). Additionally, vibration has been shown to lower recruitment thresholds of motor units compared to voluntary contractions, possibly resulting in a more rapid activation of the high threshold fast twitch motor units (Rittweger, Beller, & Felsenberg, 2000; Rittweger, Mutschelknauss, & Felsenberg, 2003; Romaiguere, Vedel, & Pagni, 1993). These mechanisms may indicate that the use of vibration can be used as a viable warm-up to increase muscle temperature by neuromuscular stimulation before an athletic competition (Cormie, Deane, Triplett, & McBride, 2006). Acute whole-body vibration has been shown to increase vertical jump height (VJH), in comparison to the control condition which included no vibration. The results of this study suggest that whole body vibration (WBV) may be a plausible warm-up procedure for increasing vertical jump from stimulating the recruitment threshold. However, the optimal dose of vibration is still unclear. Furthermore, the exact mechanism for the effect of vibration increasing vertical jump height needs to be further examined (Cormie et al., 2006).

Problem

There is no consensus regarding the specific style, intensity of warm-up protocols, or the time of application of a warm-up prior to training or competition for improving power. The research has indicated most sport specific methods have either decreased power from therapist massage and static stretching, or no change in power through SMR. However, it appears that WBV has an improvement on power production. There is also controversy in how to apply the warm-up techniques in order to provide an increase in athletic performance. This involves the specific time spent foam rolling or will combining a SMR technique with vibration improve or have a positive effect on power? Investigating isolated vibration foam rolling, as a proper warm-up prior to performing high speed anaerobic movements has not been explored. Effects of foam rolling needs to be further examined because this knowledge is essential for athletes who have a limited amount of time for effective warm-up and need to know if the methods they are using are going to negatively impact performance. Athletes and coaches should be aware if pre-competition foam rolling with and without vibration is actually helping or hindering specific performance variables. Therefore, the purpose of this study was to compare vibration foam rolling, non-vibration foam rolling, and no warm-up applied to a specific group of muscles on the lower extremities to determine the effect on jump height.

Hypothesis

There will be no significant difference in vertical jump height between no warm-up, vibration foam rolling, and non-vibration foam rolling performed on the lower extremities on jump height. The alpha level was set at $p \leq .05$.

Delimitations/Limitations

The study was delimited to 15 collegiate men and women basketball, women's volleyball, and football athletes from a Division I AA sports program. The intervention was delimited to the Vibra roller (Iheartsynergee, Grand Portage, MN), which contains a vibrating component with optional use.

Assumptions

An assumption was made that participants did not engage in any heavy physical activity or exercise one day prior to the day of testing to ensure validity of the vertical jump test.

Significance

The significance of this study was to clarify the effect of SMR and isolated muscle vibration as being a valid pre-competition technique for power production, and in doing so, to assist athletes in performance enhancement endeavors.

Summary

This chapter provides a discussion of the controversy surrounding static stretching, MFR, SMR, and WBV as an effective warm-up prior to performing an explosive dynamic movement. This chapter discusses the positive and negative effects of each of these proposed techniques, as well as the debatable theories behind the outcomes on muscle force production upon performing each technique. This chapter also concludes with suggestions regarding what studies need to further investigate surrounding specific warm-up protocols.

Chapter 2

Review of Literature

Introduction

The purpose of this study was to compare vibration foam rolling, non-vibration foam rolling, and no warm-up applied to a specific group of muscles on the lower extremities to determine the effect on jump height. This chapter provides research literature of various pre-competition techniques used to increase power production and enhance athletic performance.

Power and Sports Needs

Skeletal muscle power includes two basic components of dynamic strength and speed (McArdle, Katch, & Katch, 2010). These two components generate peak power (PP) which is the highest power output observed during an initial 5-second period, indicating the energy-generating capacity of the immediate high energy phosphate system (McArdle et al., 2010). Examples of such movements that stress this system are sprinting, jumping, changing direction, throwing, kicking and striking, which are components of the vast majority of sports (Cormie, McGuigan, & Newton, 2011).

The ability to generate skeletal muscle power is a well-known predictor of sports performance (Baker, 2001; Baker & Newton, 2008; Garhammer & Gregor, 1992; McArdle et al., 2010). Since power is the product of force and velocity, it is important that both of these components be addressed when developing muscular power. Since force and velocity are not independent of one another, when the velocity of a movement increases past the ability of the muscle to contract maximally, the force of the muscle used to perform movement may decrease during the concentric muscle action (Marques, 2011). As a result of this, maximal power is achieved through an ideal blend of force and velocity (Marques, 2011). Understanding the factors that affect and enhance power output is not only beneficial for the growth of the athlete, but also for strength coaches in achieving success with their athletes.

The force velocity relationship represents a characteristic property of muscle that dictates its power production capacities (Bottinelli et al., 1999; Caiozzo, Perrine, & Edgerton, 1981; Cormie et al., 2011). As the velocity of a concentric muscle action is increased, less force is capable of being generated during that contraction (Cromie et al., 2011). This is true for a given muscle group activated at a constant level due to actin-myosin cross-bridge cycling. In addition, because it takes a fixed amount of time for cross-bridges to attach and detach, the total number of cross-bridges attached decreases with increasing velocity of muscle shortening (Cormie et al., 2011). Due to the fact that the amount of force generated by a muscle depends on the number of attached cross-bridges, force production decreases as the velocity of the contraction increases and power, is maximized at a combination of submaximal force and velocity (Lieber, 2010).

Measurements of the force-velocity relationship during movements are complicated by aspects such as mixed fiber composition involving fast and slow twitch muscle fibers, anatomical joint configuration involving main joints used for power production, and levels of neural activation involving muscle force and power velocity relationships. (Edgerton, Roy, & Gregor, 1986; Faulkner, Clafin, & McCully, 1986; Gregor et al., 1979; Herbert & Gandevia, 1995; Maclntosh & Holash, 2000; Perrine, 1986; Perrine & Edgerton, 1978; Wickiewicz et al., 1984). Despite these limitations, examination of the force-velocity relationship during concentric or eccentric movements quantifies the ability of the intact neuromuscular system to function under various loading conditions, which is essential to understanding maximal power production during human movements (Cormie et al., 2011).

The ability of skeletal muscle to generate force is critically dependent on sarcomere length. The greatest potential for force production on activation of the cross bridge cycle exists when the sarcomere length provides for optimal overlap between the actin and myosin filaments (Edman, 1966; Gordon et al., 1966; Lieber et al., 1994). At this length, cross-bridge interaction is maximal, which allows for the greatest levels of active tension development (active muscle force) (Edman, 1966; Gordon et al., 1966; Lieber et al., 1994). Force production is impaired when sarcomere lengths are shortened below the optimal length due to the overlap of the actin filaments from the opposite ends of the sarcomere (Lieber, 2010). When stretching a sarcomere beyond its optimal length, it reduces the force production capacity, and at longer lengths cross-bridge interaction is decreased as a result of less overlap between the actin-myosin filaments (Edman, 1966; Gordon et al., 1966; Lieber et al., 1994). While muscular power is identified by the force-velocity relationship, the length-tension relationship influences the ability of muscle fibers to develop force and therefore, plays an important role in maximal muscular power production (Cormie et al., 2011).

Methods used to enhance power output

Static stretching. Static stretching is traditionally used as part of a warm-up to increase flexibility or pain free joint ROM in attempt to promote better performances (Vetter, 2007). It is believed that the slow, controlled movement of static stretching allows the stretch to be performed easily and safely, with reduced risk of injury compared with other forms of stretching (Smith, 1994). However, studies have suggested that pre-exercise stretching may temporarily compromise a muscle ability to produce force (Behm & Chaouachi, 2011; Behm et al., 2004; Behm et al., 2001; Power, Behm, Cahill, Carroll, & Young, 2004). In addition, some of the measured parameters have included jump height or distance, peak vertical power or velocity, time in air and ground contact time, maximal voluntary contraction force, isokinetic torque, muscle activation, musculotendinous stiffness, muscular vibrations, reaction and movement time, balance and proprioception (Fowles et al., 2000; McNeal & Sands, 2003; Vetter, 2007; Young et al., 2005).

Previous research has found that static stretching produces an increase in the range of motion of the lower limb joints, but decreases force production (Behm et al., 2001; Bradely et al., 2007; Church et al., 2001; Cornwell et al., 2001; Fowles et al., 2000; McNeal & Sands, 2003; Nelson et al., 2001; Unick et al., 2005; Young et al., 2001; Wiktorsson-Moller, Oberg, Ekstrand, & Gillquist, 1983). Two hypotheses have been proposed as to why static stretching reduces force production that includes neural and mechanical factors. Neural factors include decreased muscle activation, and altered reflex sensitivity that is explained by messages that are sent from the brain through the nerves for the muscle to contract (Wiktorsson-Moller et al., 1983). In addition, mechanical factors involve viscoelastic properties that may affect the muscle such as the length-tension relationship. The length-tension relationship refers to the length of a fiber and the force that fiber can produce at that length (Unick et al., 2005; Young et al., 2001; Wiktorsson-Moller et al., 1983).

A study that measured the acute effects of static stretching on peak torque and mean power found a 2.8% decrease in peak torque and a 3.2% decrease in mean power. It was hypothesized that static stretching may have altered the length-tension relationship and/or the plastic deformation of connective tissues such that the maximal force producing capabilities of the musculotendinous unit could be limited (Vetter 2007). In addition, previous researchers have suggested that the angle-torque relationship during maximal concentric isokenetic muscle actions may indicate information regarding the length tension relationship. It is possible that, therefore, stretching-induced alterations in the length-tension relationship may be manifested through changes in the angle-torque relationship, which, in turn, may be evident to changes in the area under the angle-torque curve (Vetter, 2007).

However, a different study suggested that changes in peak torque after static stretching could be due to changes in the neuromuscular and mechanical properties of a muscle, whereas decreases after 15 minutes were caused by impaired mechanical function from deformation in the supporting structures of a muscle (Fowles et al., 2000). Consequently, restoration of jump performance after 15 minutes was probably due to recovery of voluntary muscle activation and increased stiffness in the musculotendinous unit, as the duration of stretching in this study did not cause long-term changes to the contractile properties of the muscle (Fowles et al., 2000).

Massage therapy. Massage has been defined as a mechanical manipulation of body tissues with rhythmical pressure and stroking for the purpose of promoting health and well-being (Cafarelli & Flint, 1992). Many claims are made about massage, but few are backed by empirical data regarding either mechanisms or effects (Goodwin, Glaister, Howatson, Lockey, & McInnes, 2007). Possible mechanisms for the effects of massage have been categorized as biomechanical, physiological, neurological, and psychological (Weerpong, Hume, & Kolt, 2005).

The use of sport massage for athletics follows several general approaches, such as preparation for competition, between competitions to assist in recovery from competition, rather than treatment for specific problems (Leivadi, Hernandez-Reif, & Field, 1999). The large proportion of massage application in sports events is due to many coaches and athletes holding the belief based on observations and experiences, that massage can provide several benefits to the body such as increased blood flow, reduced muscle tension, and neurological excitability. However there is limited scientific evidence to support the use of massage for enhancing performance (Weerpong et al., 2005).

Previous research has linked manual massage therapy with similar characteristics to statistic stretching. It has been found that manual massage therapy increases ROM and shows mechanisms for improving flexibility while decreasing in force production (Arazi, Asadi & Hoseini, 2012). Mechanisms suggested for improving flexibility induced by massage therapy is that massage is an effective way to increase lymphatic and venous drainage, squeeze out metabolic waste products, promote deeper relaxation of tissues and making the tissue interface more mobile (Paine, 2000). These claims account for the increase in flexibility associated with massage or static stretching reducing stiffness at a fiber level and increasing muscle compliance (Arazi et al., 2012).

Massage can increase muscle length but will also affect performance in power events (Arabaci, 2008). Two studies found that manual massage provided significant degrades in vertical jump and sprint performance. However, massage and static stretching of the hamstring muscle group increased passive ROM in the hip and lowered limb joints (Crossman, Chateauvert & Weisberg, 1984; MeKechnie et al., 2007). Because manual massage therapy is heavily compared to static stretching, suggestions for a decrease in muscle force are very similar to one another involving the skeletal muscle being lengthened related to the length-tension relationship. There is no consensus on the type, style, application, duration, intensity, number of strokes applied, or the time prior to training competition (Paine, 2000).

Self-induced myofascial release. Self-induced myofascial release (SMR) is a technique that involves an individual using their own body mass on a foam roller to exert pressure on the soft tissue that can treat soft tissue restrictions. The SMR technique involves small undulations back and forth over a dense foam roller, starting at the proximal portion of the muscle, working down to the distal portion of the muscle or vice versa (Paolini, 2009). The small undulations place a direct and sweeping pressure on the soft tissue, stretching the tissue and generating friction between the soft tissue of the body and the foam roller.

In addition, the friction generated from the undulations causes warming of the fascia to take on a more fluid-like form (Sefton, 2004). Furthermore, foam rolling corrects muscular imbalances, alleviates muscle soreness, relieves joint stress, improves neuromuscular efficiency, and improves range of motion (ROM) (Barne, 2005; Curran, Fiore, & Crisco, 2008; Swann & Graner, 2002). However, the effects of SMR via foam rolling on power production have hardly been investigated.

Recent research found that neuromuscular performance of the quadriceps revealed no significant differences in any performance measurements (muscle force, rate force development (RFD), and muscle activation) between the control condition (ROM, maximum voluntary contraction (MVC), and interpolated twitch technique (ITT)) and foam roller conditions when foam rolling for two minutes. A significant increase in knee joint ROM at two min post- (12.7%) and 10 minutes post-foam rolling (10.3%) of the quadriceps muscles was found (MacDonald et al., 2013). In addition, research also found an increase in flexibility in a sit and reach test for lower back and hamstrings' flexibility at 4.3% without any significant voluntary performance detriment when performing SMR for 10 seconds (Sullivan, Silvey, Button, & Behm, 2013).

It has been suggested that the most common theory to explain ROM with myofascial release is the thixotropic property of the fascia (Sefton, 2004). This theory suggests that when undisturbed, fascia becomes more viscous and takes on a more solid like form, which can restrict movement. If heat from body weight or rolling pressure is applied to the fascia, it can become more gel-like and pliable allowing for a greater ROM which may be achieved in as little as five to 10 seconds (MacDonald et al., 2013; Sullivan et al., 2013).

In regards to power production involving SMR it has been suggested that because minimal changes seen in electromyography (EMG) activity seen following a short duration of foam rolling, perhaps there may be a EMG versus time relationship for an increase in power production. In addition, possibly shorter EMG times may cause no change in EMG and subsequent muscle force production (McKechnie, Behm, & Young, 2009). This suggest that SMR as a form of massage may only have a positive effect on joint ROM and no detrimental effect to power production when used for a short duration (Sullivan et al., 2013).

Whole body vibration. Whole body vibration is an increasingly popular means of warm up due to reports of improved strength, power, balance and bone strength (Cardinale & Bosco, 2003; Cochrane & Stannard, 2005). Neuromuscular stimulation as a result of WBV is the likely source of previously observed changes in athletic performance. The tonic vibration reflex is a response elicited from vibration directly applied to a muscle belly or tendon (Hagbarth & Eklung, 1985; Seidel, 1988). This reflex is characterized by activation of muscle spindles primarily through Ia afferents and activation of extrafusal muscle fibers through motor neurons (Cardinale et al., 2005). This application of vibration to an active muscle recently has been shown to cause a shift in EMG patterns (Issurin, Liebermann, & Tenenbaum, 1994). Vibration has also been shown to stimulate transient increases in certain hormones, such as the growth hormone (Bosco, Iacovelli, Tsarpela, & Viru, 2000). These mechanisms may indicate that the use of vibration could be a viable warm-up before athletic competition.

Previous research found that an acute bout of whole body vibration for 30 seconds led to an increase in vertical jump height (JH), in comparison with the sham condition (standing on the vibration platform with the vibration plate inactivated) (Cormie et al., 2006) The study suggest that an increase in power may have been related to muscle activity changes dealing the tonic vibration reflex by which physiological mechanisms of the muscle is altered as a result of vibration (Cormie et al., 2006) . In addition, authors suggest that it is possible that other physiological parameters that were not measured could have possibly influenced an increase in muscle force such as hormone releases or an acute increase in norepinephrine levels that can function as neurotransmitters to the muscles (Di Loreto et al., 2004).

From the previously mentioned study, WBV appears to be a plausible warm-up procedure for increasing vertical jump. However, the optimal dose of vibration is still unclear. The findings of this study were specific to the vibration settings used at a frequency of 30 Hz and an amplitude of 2.5mm (Cormie et al., 2006). It appears that vibration can have a potentiating effect on jump height. The exact mechanism for the effect of vibration on increasing vertical jump height needs to be further investigated, because change in muscle activity was not observed in the previous investigation (Cormie et al., 2006). In addition, the use of WBV as a warm-up procedure should be considered for coaches and strength and conditioning coaches in particular.

Conclusion

In conclusion, it is apparent that choosing the best possible pre-event warm-up routine has many questions yet to be answered. Throughout this review of literature, it is clearly demonstrated that a variety of methods have been developed to help increase power production with no conclusive evidence to which one is superior. Vibration as an intervention combined with foam rolling could represent a promising new method for enhancing power production. This has relevance particularly for athletes who require higher power output through the ground vertically in sport.

Chapter 3

Methods

Introduction

The purpose of this study was to compare vibration foam rolling, non-vibration foam rolling, and no warm-up applied to a specific group of muscles on the lower extremities to determine the effect on jump height. In this chapter the methods that are discussed include: the experimental approach, experimental participants, explanation of foam rolling, jump reach test, and the statistical analysis.

Participants

Eighteen collegiate athletes (9 females & 9 males) volunteered from current men's and women's basketball, football, and women's volleyball teams at a Division I university. The research design was a randomized crossover design so that all participants served as their own control by participating in all three interventions which consisted of no warm-up, non-vibration foam rolling (FRNV), and vibration foam rolling (FRV). Three participants were unable to complete all tests and their data were removed from all analysis.

Experimental Approach

Before this study was conducted, approval from the Institutional Review Board for Human Subjects (IRB) of Eastern Washington University was obtained. Upon approval from the IRB, participants were invited to partake in this study. Participants were approached in Eastern Washington University's strength and conditioning weight room where a flyer was posted explaining the study and asking for volunteers. Any athlete who expressed interest was given specifics of the study including the aims, nature, benefits, and potential risks of the study. After the explanation of the study, anyone expressing continued interest was given an informed consent and scheduled for the initial session. To participate in the study, participants brought their signed informed consent to the familiarization session. The familiarization trial was scheduled the Friday before the testing week began.

Each participant visited Eastern Washington University's indoor field house sports facility to receive instructions for the familiarization trial and to practice the Vertec vertical jump reach test. The session included learning instructions on foam roll techniques for specific muscles groups. In addition, height, weight, age, sport, and standing reach height were recorded. They were also scheduled for three testing days. During the week of testing, participants were asked not to engage in any heavy physical activity or exercise to ensure the validity of the test. Participants were encouraged to eat no later than two hours prior to testing. Participants were tested at the same time on each day of testing to reduce within subject variation.

The testing began three days after the familiarization session to be able to test on Monday, Wednesday, and Friday of the same week. On each day of testing, participants completed one of the following interventions in randomized orders (no warm-up, FRNV, FRV) with a vertical jump immediately following each condition. When participating in the no warm-up condition, participants performed the vertical jump after sitting for the same amount of time as when foam rolling or vibration rolling. During each test session, participants were encouraged to achieve maximal performance.

Interventions

Self Myofascial Release

In both passive warm-ups the Vibra-roller was used to massage the lower extremities in specific order including the hamstrings quadriceps, gastrocnemius and soleus, both on the left and right leg individually for one and a half minutes per muscle group, equaling six minutes total per leg. This time was chosen based on previous literature which suggested that a constant pressure should be applied to the muscle from 60-90 seconds up to five minutes or until a release is felt by the individual (Paolini, 2009; Stone, 2000). Participants were instructed to support themselves from a horizontal position with two hands on the ground with the intent of placing maximal body weight onto the foam roller.

Vertec.

The Vertec was used to assess each participant's vertical jump height to determine peak power. Each participant was required to perform a bilateral countermovement vertical jump from a stationary position with the intention of obtaining maximum height. They were allowed to use an arm swing for momentum, provided it did not alter their vertical height alignment.

To determine the vertical jump measurement, the Vertec was set at a standard height of 78 inches (6' 6"). To determine reach, the participant then performed a maximal static reach stretch with feet flat on the floor touching the highest colored marker they could reach. The participant's highest static stretch measurement from the tip of the middle finger was then recorded. Next the Vertec was adjusted to their anticipated maximal reach mark, and the participant was placed into position to start the first vertical jump. Each participant initially started from the same jumping point that was measured 2.5 inches directly behind the lowest colored marker of the Vertec where a piece of tape was placed on the ground. This was to ensure that each participant was jumping from the same take-off point.

Once a jump attempt had been completed, the measurement of the jump height was recorded using inches. Participants were allowed three attempts and were given verbal encouragement to jump as high and as straight up as possible. The highest score achieved was used for the measured vertical jump height. Shuffling feet or false steps invalidated the jump and resulted in another attempt. Participants were observed very closely to ensure that their feet stayed in a stationary position and that no alterations in jumping technique occurred. Peak power production was also recorded for each intervention using the Sayers equation ([51.9 * CMJ height (cm)] + [48.9 * Body mass (kg)] – 2007).

Statistical Analysis

All statistical analyses were conducted using IBM SPSS version 20.0. Descriptive statistics of all variables were determined, including age, height, weight, standing reach and vertical jump. A repeated measures one-way ANOVA test was conducted to determine whether there were differences between the three interventions: no warm-up, non-vibration, and vibration. The Alpha level was set at $p \leq 0.5$. If significant differences were found, the Bonferoni post hoc test was used to see which treatments differed significantly and exactly where those significant differences occurred.

Summary

This chapter provided a description of the methodology used in this study. This chapter discusses the experimental approach, participants, procedures, and the statistical analysis employed in this study.

Chapter 4

Results

Introduction

The purpose of this study was to compare vibration foam rolling, non-vibration foam rolling, and no warm-up applied to a specific group of muscles on the lower extremities to determine the effect on jump height. The research hypothesis in this study assumed that foam rolling with and without vibration would produce a positive effect on jump height. This chapter reviews the statistical analyses used to assess these data and the corresponding results.

Demographics

Eighteen healthy athletes who played Division I collegiate sports consisting of high anaerobic activity where power is an important key element volunteered to participate. The-sports were men's and women's basketball, football and women's volleyball. Three participants were unable to complete all three test conditions so their data were removed from the analysis. Thus 15 participants completed the study (females, n = 8 and males, n = 7). Descriptive variables were recorded at the initial meeting including their age in years (20.4 ± 1.5), weight in pounds (198.3 ± 58.4), height in inches (72.8 ± 5.7), and standing reach in inches (97.5 ± 6.8).

Descriptive Statistics

Prior to running the Repeated Measures ANOVA tests for distribution, the Shapiro Wilks test, and tests for skewness and kurtosis were all normal. The jump height means and standard deviations for each are presented in Table 1. They are presented with the group combined and separated by sex. In Figure 1 the Shapiro Wilks test box plots showed three outliers. Because the sample was so small even though the Shapiro Wilks test showed a normal distribution, the analysis was run a second time with the outliers removed. The group means and standard deviations with the outliers removed can be seen in Table 2. Peak power average is presented in Table 3.

Table 1 Means and standard deviations for each condition total and by sex

	No warm-up	No Vibration	Vibration
Subjects	M±SD	M±SD	M±SD
Combined (N = 15)	21.60±5.14	21.90±4.36	21.50±4.58
Men (n = 7)	21.20±2.56	21.8±1.96	21.40±1.48
Women (n = 8)	19.25±3.02	19.75±2.83	19.43±3.16

Figure 1 Box Plot showing outlier

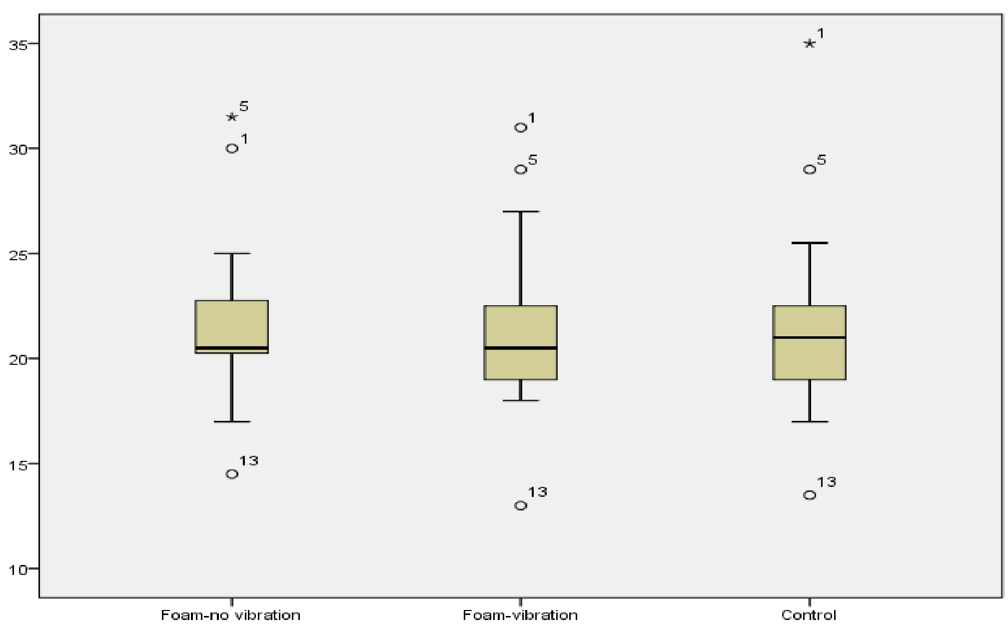

Table 2 Jump Height (inches) Means and Standard Deviations without Outliers

	No warm-up	FRNV	FRV
Subjects	M±SD	M±SD	M±SD
Combined (n = 12)	20.54±2.26	21.04±2.01	20.79±2.51
Men (n = 5)	24.29±5.93	24.35±4.67	23.86±5.02
Women (n = 7)	20.07±2.09	20.50±2.02	20.35±1.93

Table 3 Peak Power Average

	No warm-up	FRNV	FRV
Combined (N = 12)	5330 w	5362 w	5307 w

Note. Peak power measurement = watts

Repeated Measures ANOVA

The Shapiro-Wilk test found no significant difference ($p > .05$) from a normal distribution. A repeated measures ANOVA was calculated to compare the mean scores of no warm-up jump height to the mean vibration and non-vibration jump height scores. No significant effect was found ($F(2,28) = .669$, $p > .05$) with all subjects included. A second repeated measures ANOVA was then run with outliers removed, but the results were still non-significant ($F(2,22) = 2.152$, $p > .05$).

Summary

This chapter presented a description of the statistical analysis used in this study. Descriptive variables were presented, and the results of the multiple repeated measures.

Chapter 5

Discussion

Introduction

The purpose of this study was to compare vibration foam rolling, non-vibration foam rolling, and no warm-up applied to a specific group of muscles on the lower extremities to determine the effect on jump height. This chapter discusses an overview of the current study, a comparison to previous research, and recommendations provided for future research.

Discussion

Similar to previous studies on massage therapy or SMR techniques, this study was unable to demonstrate a significant effect on jump reach as a measure of power when using either vibration or non-vibration foam rolling as a pre-event warm-up. Because the population was small and there could have been a sex effect on the distribution, repeated measures ANOVA's were run on the data separated by sex. No significant difference was found within male or female athletes likely due to the small sample size. The main findings in this study are similar to research following other forms of SMR no matter the outcome measured or the form of manipulation.

Vibration foam rollers are a new addition to SMR manipulations. There is no research at present using vibration foam rollers. In the present study vibration foam rolling produced the lowest peak power out of the three conditions (no warm-up, FRNV, and FRV) though the differences were not significant. The research on increasing ROM with massage used two conditions, external massage done by a massage therapist (Goodwin et al., 2007; McKechine et al., 2007), or foam rolling (Sullivan et al., 2012). A question that still needs to be answered is whether the addition of the vibration masks the sensation of pressure such that the SMR was actually less effective when applied with vibration.

The studies that measured power found no effect of massage (Goodwin et al., 2007; McKechine et al., 2007) or foam rolling (Sullivan et al., 2013). One study that also used foam rolling considered physiological changes rather than whether the intervention impacted performance (MacDonald et al., 2013). They found no significant changes in voluntary or evoked muscle properties following foam rolling. Related to power performance they did find a reduction in deep mechanoreceptor activation following two short, two minute bouts of foam rolling and suggested that decreases in spinal motor neuron excitability along with depression in the Hoffmann's reflex (H-reflex) can occur due to a short bout of massage.

In addition, the H-reflex size is dependent on the amount of massage pressure and different pressures may produce variable inhibition on the mechanoreceptors (MacDonald et al., 2013). While the subjects were all instructed on how to use the foam rollers, no measure was done to determine the extent of the pressure applied. Because the vibrating roller could give the sensation of more pressure it is also possible less force was used with the vibrating roller. In each case looking at Table 1 and 2 the no vibration jump means were the highest values and when outliers were removed the vibration was the lowest in men.

Probably more important, the results of these studies and the present study as well, demonstrated no effect on power or show a reduction in power either. The present study was unable to verify suggestions that have been made for why SMR should improve power if it is able to increase ROM. However, the present study did not measure ROM because the primary focus was on the outcome of power production. Two primary explanations suggested by the literature include viscoelastic properties positively affecting the length tension relationship and neural factors including muscle activation or altered reflex sensitivity (Hemmings, 2001; Wiktorsson-Moller et al., 1983). Unfortunately, at present no studies including the present study have demonstrated increased power. All have shown slight variations in power and no significant decreases in power suggesting the foam roller is acting more like massage than static stretching.

The major weakness of the present study was likely power. While a power analysis was done prior, no studies showing increased anaerobic power were available to use in the formula. The present study did not measure ROM only power in the jump reach and found the same outcome as all previous studies. The loss of data from three subjects further decreased the potential power. While sex should not impact the outcome of variation in jump heights, due to the differences in height and weight between the men and women might have impacted the outcome. In addition, the populations were too small if divided by sex to have adequate power to analyze separately.

Recommendations

The findings in this study necessitate the need for future studies dealing with SMR.

- The first recommendation is to increase the sample size. As well as incorporating a more homogenous group such as, just males, just females, or possibly by a particular sport. Since no research has been done to show an improvement in anaerobic power and the fact that the results would not be able to be generalized would not be a significant limitation.

- The second recommendation is to combine the measurement of power to the other measures including ROM and muscle activation to determine if the changes suggested actually occur and if they are related to no change of SMR in anaerobic power.

Summary

In summary, vibration and non-vibration foam rolling do not provide any significant enhancement in power production. However, the two conditions do not significantly hinder power production either. This chapter provides an overview of the current study as well as an in depth discussion on previous research incorporating some type of SMR to enhance athletic performance. More investigations on SMR are required to determine the best possible technique to enhance anaerobic power.

References

Arabaci, R. (2008). Acute effects of pre-event lower limb massage on explosive and high speed motor capacities and flexibility. *Journal of Sports Science and Medicine, 7*(4), 549-555.

Arazi, H., Asadi, A., & Hoseni, K. (2012). Comparison of two different warm-ups (static-stretching and massage): Effects on flexibility and explosive power. *Journal of Kinesiology,* 1, 55-59.

Baker, D. (2001a). Comparison of upper-body strength and power between professional and college-aged rugby players. *Journal of Strength and Conditioning,* 15, 30-35.

Baker, D. (2001b). A series of studies on the training of high-intensity muscle power in rugby league football players. *Journal of Strength and Conditioning,* 15, 198-209.

Baker, D. G., & Newton, R. U. (2008). Observation of 4-year adaptations in lower body maximal strength and power output in professional rugby league players. *Journal of Australian Strength and Conditioning, 16*(1), 3-10.

Barnes, M. (2007). The basic science of Myofascial release: Morphologic change in connective tissue. *Journal of Body Movement Therapy, 1*(4), 231-238.

Behm, D. G., Bambury, A., Cahill, F., & Power, K. (2004). Effect of acute static stretching on force, balance, reaction time, and movement time. *Medicine and Science in Sports and Exercise*, *36*(8), 1397-1402.

Behm, D. G., Button, D. C., & Butt, J. C. (2001). Factors affecting force loss with prolonged stretching. *Canadian Journal of Applied Physiology, 26*(3), 261-272.

Behm, D. G., & Kibele, A. (2007). Effects of differing intensities of static stretching on jump performance. *European Journal of Applied Physiology, 101*(5), 587-594.

Behm, D., & Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. *European Journal of Applied Physiology, 111*(11), 263-265.

Bishop, D. (2003). Performance changes following active warm-up and how to structure the warm-up. *Journal of Sports Medicine, 33*(7), 483-498.

Brockett, C., Morgan, D., & Proske, U. (2001). Human hamstring muscles adapt to eccentric exercise by changing optimum length. *Medicine and Science in Sports Exercise*, 33:783-790.

Bompa, T., & Carrera, M. (2005). Periodization training for sports: Science-based strength and conditioning plans for 20 sports. *Human Kinetics*, 247-253.

Bosco, C., Colli, R., Introini, M., Cardinale, O., Tsarpela, A., Madella, J., & Viru, A. (1999). Adaptive responses of human skeletal muscle to vibration exposure. *Clinical Physiology, 19*(2), 183-187.

Bottinelli, R., Pellegrino, M., Canepari, M., Rossi, R., & Reggiani, C. (1999). Specific contributions of various muscle fibre types to human muscle performance: An in vitro study. *Journal of Electromyography and Kinesiology, 9*(2), 87-95.

Bradley, P. S., Olsen, P. D., & Portas, M. D. (2007). The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *Journal of Strength and Conditioning Research, 21*(1), 223-226.

Cafarelli, E., & Flint, F. (1992). The role of massage in preparation for and recovery from exercise. *Journal of Sports Medicine, 14*(1), 1-9.

Caiozzo, V. J., Perrine, J. J., & Edgerton, V. R. (1981). Training-induced alterations of the in vivo force-velocity relationships of human muscle. *Journal of Applied Physiology*, 750-754.

Cardinale, M., & Lim, J. (2003). Electromyography activity of vastus lateralis muscle during whole-body vibrations of different frequencies. *Journal of Strength & Conditioning Research, 17*(3), 621-624.

Chaouachi, A., Castahna, C., Chtara, M., Brughelli, M., Turki, O., Galy, O., Behm, D. G. (2010). Effect of warm-ups involving static or dynamic stretching on agility, sprinting, and jumping performance in trained individuals. *Journal of Strength and Conditioning Research, 24*(8), 2001-2011.

Church, J. B., Wiggins, M. S., Moode, F. M., & Crist, R. (2001). Effect of warm-up and flexibility treatments on vertical jump performance. *Journal of Strength and Conditioning Research, 15*(3), 332-336.

Close, R. I. (1972). Dynamic properties of mammalian skeletal muscles. *Physiological Reviews, 52*(1), 129-197.

Cochrane, D. J., & Stannard, S. R. (2005). Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *British Journal of Sports Medicine, 39*(11), 860-865.

Cormie, P., Deane, R. S., Triplett, T., & McBride, J. M. (2006). Acute effects of whole-body vibration on muscle activity, strength, and power. *Journal of Strength and Conditioning Research, 20*(2), 257-261.

Cormie, P., McCuigan, M. R., & Newton, R. U. (2011). Developing maximal neuromuscular power. *Journal of Sports Medicine, 41*(1), 17-38.

Cornwell, A., Nelson, A. G., Heise, G. D., & Sidaway, B. (2001). Acute effects of passive muscle stretching on vertical jump performance. *Journal of Human Movement Studies, 40*(4), 307-324.

Cornwell, A., Nelson, A. G., & Sidaway, B. (2002). Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. *European Journal of Applied Physiology, 86*(5), 428-434.

Costa, P. B., Ryan, E. D., Herda, T. J., Walter, A. A., Hoge, K. M., & Cramer, J. T. (2012). Acute effects of passive stretching on the electromechanical delay and evoked twitch properties: A gender comparison. *Journal of Applied Biomechanics, 28*(6), 645-654.

Cramer, J. T., Housh, T. J., Johnson, G. O., Miller, J. M., Coburn, J. W., & Beck, T. W. (2004). Acute effects of static stretching on peak torque in women. *Journal of Strength and Conditioning Research, 18*(2), 236-241.

Di Loreto, C., Ranchelli, A., Lucidi, P., Murdolo, G., Parlanti, N., De Cicco, A., Tsarpela, O., Annino, G., Bosco, C., Santeussanio, F., Bolli, G., & De Feo, P. (2004). Effects of whole body vibration exercise on the endocrine system of healthy men. *Journal of Endocrinal,* 27:323-327.

Edgerton, V. R., Roy, R. R., Gregor, R. J., & Rugg, S. (1986). Morphological basis of skeletal muscle power output., 43-64.

Edman, K. A. (1966). The relation between sarcomere length and active tension in isolated semitendinosus fibres of the frog. *The Journal of Physiology, 183*(2), 407-417.

Egan, A. D., Cramer, J. T., Massey, L. L., & Marek, S. M. (2006). Acute effects of static stretching on peak torque and mean power output in National Collegiate Athletic Association Division I women's basketball players. *Journal of Strength and Conditioning Research, 20*(4), 778-782.

Evetovich, T. K., Nauman, N. J., Conley, D. S., & Todd, J. B. (2003). Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. *Journal of Strength and Conditioning Research, 17*(3), 484-488.

Faulkner, J. A., Claflin, D. R., & McCully, K. K. (1986). Power output of fast and slow fibers from human skeletal muscles, 81-94.

Ferber, R., Osternig, L., & Gravelle, D. (2002). Effect of PNF stretch techniques on knee flexor muscle EMG activity in older adults. *Journal of Electromyography and Kinesiology, 12*(5), 391-397.

Fletcher, I. M., & Anness, R. (2007). The acute effects of combined static and dynamic stretch protocols on fifty-meter sprint performance in track-and-field athletes. *Journal of Strength & Conditioning Research, 21*(3), 784-787.

Fletcher, I. M., & Jones, B. (2004). The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *Journal of Strength and Conditioning Research, 18*(4), 885-888.

Fowles, J., Sale, D., & MacDougall, J. (2000). Reduced strength after passive stretch of the human plantar flexors. *Journal of Applied Physiology, 8:* 1179-1188.

Funk, D. C., Swank, A. M., Mikla, B. M., Fagan, T. A., & Farr, B. K. (2003). Impact of prior exercise on hamstring flexibility: A comparison of proprioceptive neuromuscular facilitation and static stretching. *Journal of Strength and Conditioning Research, 17*(3), 489-492.

Galloway, S., Watt, J., & Sharp, C. (2004). Massage provision by physiotherapists at major athletic events between 1987 and 1998. *Journal of Sports Medicine, 38*(20), 235-237.

Garhammer, J., & Gregor, R. J. (1992). Propulsion forces as a function of intensity for weightlifting and vertical jumping. *Journal of Strength and Conditioning*, 6: 129-134

Goodwin, J. E., Glaister, M., Howatson, G., Lockey, R. A., & McInnes, G. (2007). Effect of pre-performance lower-limb massage on thirty-meter sprint running. *Journal of Strength and Conditioning Research, 21*(4), 1028-1031.

Gordon, A., Huxley, A., Julian., F. (1966). The variation in isometric tension with sarcomere length in vertebrae muscle fibres. *Journal of Applied Physiology,* 184: 170-192.

Gregor, R. J., Edgerton, V. R., Perrine, J. J., & Campion, D. S. (1979). Torque-velocity relationships and muscle fiber composition in elite female athletes. *Journal of Applied Physiology,* 388-392.

Hagbarth, K., & Eklung, G. (1985). Motor effects of vibratory stimuli. *Muscular effects and motor control,* 177-186.

Hayes, P. R., & Walker, A. (2007). Pre-exercise stretching does not impact upon running economy. *Journal of Strength and Conditioning Research, 21*(4), 1227-1232.

Hemmings, B. (2001). Physiological, psychological and performance effects of massage therapy in sport: A review of the literature. *Journal of Physiological Therapy of Sport*, 2: 165-170.

Herbert, R. D., & Gandevia, S. C. (1995). Changes in pennation with joint angle and muscle torque: In vivo measurements in human brachialis muscle. *Journal of Physiology*, 484, 523-532.

Holcomb, W. R. (2000). Stretching and warm-up. *Essentials of Strength Training & Conditioning.* 22, 70-75.

Issurin, V., Liebermann, D., & Tenenbaum, G. (1994). Effect of vibratory stimulation training on maximal force and flexibility. *Journal of Sports Science,* 12:561-566.

Knott, M., Voss, D. E., Hipshman, H. D., & Buckley, J. B. (1968). Proprioceptive neuromuscular facilitation: Patterns and techniques. *Hoeber Medical Division, Harper and Row NY,* 203-206.

Knudson, D. (1999). Stretching during warm-up: Do we have enough evidence? *Journal of Physical Education, Recreation and Dance*, *70*(7), 24-27.

Knudson, D., Bennett, K., Corn, R., Leick, D., & Smith, C. (2001). Acute effects of stretching are not evident in the kinematics of the vertical jump. *The Journal of Strength and Conditioning Research, 15*(1), 98-101.

Kokkonen, J., Nelson, A. G., & Cornwell, A. (1998). Acute muscle stretching inhibits maximal strength performance. *Research Quarterly for Exercise and Sport, 69*(4), 411-415.

Leivadi, S., Hernandez-Reif, M., Field, T., O'Rourke, M., D'Arienzo, S., Lewis, D., Kuhn, C. (1999). Massage therapy and relaxation effects on university dance students. *Journal of Dance Medicine and Science, 3*(3), 108-112.

Lieber, R. L. (2002). Skeletal muscle structure, function, and plasticity: The physiological basis of rehabilitation. *Journal of Human Kinetics*.

Liebermann, D., & Tenebaum, G. (1994). Effect of vibratory stimulation training on maximal force and flexibility. *Journal of Sports Science,* 561-566.

Little, T., & Williams, A. G. (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*(1), 203-207.

MacDonald, G. Z., Penney, M. D., H., Mullaley, M. E., Cuconato, A. L., Drake, C. D., J., Behm, D. G., & Button, D. C. (2013). An acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. *Journal of Strength and Conditioning Research, 27*(3), 812-821.

Marek, S. M., Cramer, J. T., Fincher, A. L., Massey, L. L., Dangelmaier, S. M., Purkayastha, S., Culbertson, J. Y. (2005). Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *Journal of Athletic Training, 40*(2), 94-103.

Marques, M. C. (2011). Strength in power sports: The latest scientific results. *Journal of Physical Education and Sport, 11*(2), 174-177.

McArdel, W., Katch, F., & Katch, V., (2010). Exercise Physiology: Nutrition, Energy, and Human Performance. Baltimore, MD: Wolters Kluwer.

McHugh, M. P. & Hogan, D. E., (2004). Effect of knee flexion angle on active joint stiffness. *Acta Physiology*, 180: 254-294.

McHugh, M. P. & Tetro, D. T., (2003). Changes in the relationship between joint angle and torque production associated with the repeated bout effect. *Journal of Sports Science*, 21:927-932.

McKechnie, G. J. B., Young, W. B., & Behm, D. G. (2007). Acute effects of two massage techniques on ankle joint flexibility and power of the plantar flexors. *Journal of Sports Science and Medicine, 6*(4), 498-504.

McNeal, J. R., & Sands, W. A. (2003). Acute static stretching reduces lower extremity power in trained children. *Pediatric Exercise Science, 15*(2), 139-144.

Morgan, D. L., & Proske, U. (2004). Popping sarcomere hypothesis explains stretch-induced muscle damage. *Clinical and Experimental Physiology, 31*(8), 541-545.

Nelson, A., Cornwell, A., & Heise, G. (1996). Acute stretching exercises and vertical jump stored elastic Energy. *Medicine & Science in Sports & Exercise, 28*(5), 156.

Nelson, A. G., Kokkonen, J., & Eldredge, C. (2005). Strength inhibition following an acute stretch is not limited to novice stretchers. *Research Quarterly for Exercise and Sport, 76*(4), 500-506.

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 Research, 15*(2), 241-246.

Pagaduan, J. C., Pojskic, H., Užicanin, E., & Babajic, F. (2012). Effect of various warm-up protocols on jump performance in college football players. *Journal of Human Kinetics*, 35, 127-132.

Paine, T. (2000). The complete guide to sports massage.

Paolini, J. (2009). Review of myofascial release as an effective massage therapy technique. *Athletic Therapy Today, 14*(5), 30-34.

Perrine, J. J., & Edgerton, V. R. (1978). Muscle force-velocity and power-velocity relationships under isokenetic loading. *Medicine and Science in Sports, 10*(3), 159-166.

Power, K., Behm, D., Cahill, F., Carroll, M., & Young, W. (2004). An acute bout of static stretching: Effects on force and jumping performance. *Medicine & Science in Sports & Exercise, 36*(8), 1389-1396.

Rassier, D. E., MacIntosh, B. R., & Herzog, W. (1999). Length dependence of active force production in skeletal muscle. *Journal of Applied Physiology, 86*(5), 1445-1457.

Rittweger, J., Beller, G., & Felsenberg, D., (2000). Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clinical Physiology, 20*(2), 134-142.

Safran, M. R., Seaber, A. V., & Garrett, W. E. (1989). Warm-up and muscular injury prevention: An update. *Journal of Sports Medicine, 8*(4), 239-249.

Samson, M., Button, D. C., Chaouachi, A., & Behm, D. G. (2012). Effects of dynamic and static stretching within general and activity specific warm-up protocols. *Journal of Sports Science and Medicine, 11*(2), 279-285.

Schilling, B., & Stone, M. (2000). Acute effects on strength and power performance. *Journal of Strength and Conditioning,* 22, 44-47.

Sefton, J. (2004). Myofascial release for athletic trainers, part I: Theory and session guidelines. *Athletic Therapy Today, 9*(1), 48-49.

Shellock, F. G., & Prentice, W. E. (1985). Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Journal of Sports Medicine, 2*(4), 267-278.

Shrier, I., & Gossal, K. (2000). Myths and truths of stretching: Individualized recommendations for healthy muscles. *The Physician and Sports Medicine, 28*(8), 57-63.

Shrier, I. (2004). Does stretching improve performance? A systematic and critical review of the literature. *Clinical Journal of Sport Medicine, 14*(5), 267-273.

Siatras, T., Papadopoulos, G., Mameletzi, D., Gerodimos, V., & Kellis, S. (2003). Static and dynamic acute stretching effect on gymnasts' speed in vaulting. *Pediatric Exercise Science, 15*(4), 383-391.

Smith, C. A. (1994). The warm-up procedure: To stretch or not to stretch. A brief review. *Journal of Orthopedic and Sports Physical Therapy, 19*(1), 12-17.

Stone, A. (2000). Myofascial Release. *Athletic Therapy Today*, 5:34-35.

Sullivan, K. M., Silvey, D. B., J., Button, D. C., & Behm, D. G. (2013). Roller-massager application to the hamstrings increases sit-and-reach range of motion within five to ten seconds without performance impairments. *International Journal of Sports Physical Therapy, 8*(3), 228-236.

Tessier, G. D., Draper, D. (2005). Sports Massage: An Overview. *Athletic Therapy Today,* 67-73.

Thacker, S. B., Gilchrist, J., Stroup, D. F., & Kimsey Jr., C. D. (2004). The impact of stretching on sports injury risk: A systematic review of the literature. *Medicine & Science in Sports & Exercise, 36*(3), 371-378.

Torvinen, S., Kannus, P., Sievanen, H., Jarvinen, T. A. H., Pasanen, M., Kontulainen, S., Vuori, I. (2002). Effect of 4-month vertical whole body vibration on performance and balance. *Medicine & Science in Sports & Exercise*, 1523-1528.

Unick, J., Kieffer, H. S., 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 Research, 19*(1), 206-212.

Vetter, R. E. (2007). Effects of six warm-up protocols on sprint and jump performance. *Journal of Strength and Conditioning Research, 21*(3), 819-823.

Weerapong, P., Hume, P. A., & Kolt, G., S. (2005). The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Journal of Sports Medicine, 35*(3), 235-256.

Wickiewicz, T. L., Roy, R. R., Powell, P. L., Perrine, J. J., & Edgerton, V. R. (1984). Muscle architecture and force-velocity relationships in humans. *Journal of Applied Physiology, 57*(2), 435-443.

Wiktorsson-Moeller, M., Oeberg, B., Ekstrand, J., & Gillquist, J. (1983). Effects of warming up, massage, and stretching on range of motion and muscle strength in the lower extremity. *American Journal of Sports Medicine, 11*(4), 249-252.

Woods, K., Bishop, P., & Jones, E. (2007). Warm-up and stretching in the prevention of muscular injury. *Journal of Sports Medicine, 37*(12), 1089-1099.

Young, W., & Elliott, S. (2001). Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching and maximum voluntary contractions on explosive force production and jumping performance. *Research Quarterly for Exercise and Sport*, *72*(3), 273-279.

Young, W. B., & Behm, D. G. (2003). Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *Journal of Orthopedic and Sports Physical Therapy, 33*(7), 422-423.

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