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# THE ACUTE EFFECT VIBRATING FOAM ROLLERS HAVE ON THE LOWER EXTREMITIES' ABILITY TO PRODUCE POWER

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# THE ACUTE EFFECT VIBRATING FOAM ROLLERS HAVE ON THE LOWER EXTREMITIES' ABILITY TO PRODUCE POWER

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By

Jared L. Klingenberg

Spring 2017

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MASTER'S THESIS

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## Abstract

The purpose of this study was to examine the effect that vibration through self-myofascial release in combination with a dynamic stretch routine had on maximum power output. Twenty-one collegiate volleyball athletes agreed to participate in the study. The design was a randomized cross-over design in which all participants served as their own control by participating in all three interventions, which consisted of; a) dynamic stretch routine (DS), b) non-vibrating foam rolling combined with dynamic stretch routine (NVFR), and c) vibrating foam rolling combined with dynamic stretch routine (VFR). The foam rolling protocol consisted of rolling each limb bilaterally for 30 seconds; four and a half minutes in total, and was followed with the dynamic stretch routine. Subjects then participated in the vertical jump test, using a Just Jump Mat. Each participant was given one practice attempt, and three recorded attempts that were averaged, and used for statistical analysis. Testing days were separated by a minimum of 48 hours and were completed at the same time of day. A repeated measures ANOVA was calculated to compare the mean scores of the jump height and power for each warm-up condition. This study found there to be no significant difference between jump height due to the warm-up condition ($F(2,40)=1.705$, $p=0.195$, $\eta_p^2=0.079$). This study also found there to be no significant difference between jump power due to the warm-up condition ($F(2,40)=1.754$, $p=0.186$, $\eta_p^2=0.081$). However, this study did indicate a significant difference in the perceived effectiveness of the warm-up condition ($F(2,40)=5.043$, $p=.011$, $\eta_p^2=0.201$, CI=[0.213,1.120]). In conclusion, the present study indicated that vibrating foam rolling combined with dynamic stretch did not have a significant effect on jump height in female collegiate athletes.

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# Chapter 1

## Introduction

Performing a warm-up prior to athletic participation is a universally accepted approach to prepare the body both physically, and mentally for optimum performance, while also reducing the potential risk of injury (Young & Behm, 2002). Warm-ups are categorized as either passive, or active. Passive warm-ups elevate the body's temperature through external means such as heating pads, steam baths, saunas, or hot showers (Shellock & Prentice, 1985; Bishop, 2003). In terms of collegiate athletics, this is not a practical method to prepare student-athletes as they tend to train in a team setting. Two of the most commonly used types of stretching are static or dynamic. Static stretching is considered to be a slow or passive form of stretching (Kreighbaum & Barthels, 1996). A more practical method to warm-up athletes is through an active approach. Active dynamic warm-ups are designed to increase core temperature, increase blood flow, prepare the body for exercise, and have been shown to benefit performance (Fletcher & Jones, 2004). Active warm-ups contain both general and specific properties. A general warm-up includes basic human movements, specifically jogging, cycling and calisthenics (Woods, Bishop, & Jones, 2007). As a warm-up progresses it begins to take on a more specific nature, and the movements start to closely resemble the particular activity the body is about to perform (Safran, Seaber, & Garrett, 1989). Specific warm-ups are considered to be the most effective means to prepare athletes (Faigenbaum, Bellucci, & Bernieri, 2005). In addition to dynamic stretching, self-myofascial release (SMR) and whole-body vibration (WBV) have become increasingly popular in strength and conditioning. Coaches widely utilize these implements to prepare their athletes. This review will include a brief description of static and dynamic stretching, SMR, and WBV as a means to physically prepare athletes for the rigors of practice, competition, or strength training.

Static stretching prior to exercise has been found to have a negative effect on maximal muscular performance (Bradley, Olsen, & Portas, 2007). Static stretching is described as holding a limb at its end range of motion for a specific length of time, ranging between 15-60 seconds (Norris, 1999; Young & Behm, 2002). Research suggests static stretching reduces the ability to maximally produce power due to the decreased stiffness of the musculotendinous unit (Fowles, Sales, & Macdougall, 2000). Because of this, researchers do not recommend performing static stretching immediately prior to an explosive athletic movement (Bradley, Olsen, & Portas, 2007). Instead, dynamic stretches are recommended due to its potential to increase an athlete's ability to produce power through enhanced coordination, which stimulates a greater amount of muscle fibers (Fletcher, 2010; Herman & Smith, 2008; Jaggers, Swank, Frost, & Lee, 2008; Ryan et al., 2014). Collegiate strength and conditioning professionals utilize active dynamic warm-ups because of the potential performance benefits. Regular practice and strength training is believed to cause microtrauma, which initiates an inflammatory response that if left untreated could lead to fascial scar tissue and muscular dysfunctions over time (Curran, Fiore, & Crisco, 2008). Since static and dynamic stretches do not affect fascial tissue, a technique known as self-myofascial release has been developed.

Using a variety of tools such as a foam roller, tennis ball, or lacrosse balls athletes are able to perform SMR techniques. SMR can be described as placing an individual's bodyweight on a foam roller, in order to exert pressure on the opposing soft tissue through small undulations (Curran, Fiore, & Crisco, 2008). Traditionally, athletes utilize foam rollers to perform a variety of SMR techniques, because they have the ability to treat fascial restrictions brought on by regular athletic participation. The majority of research has primarily focused on SMR as a tool for recovery and has found that it may have the ability to aid in muscular imbalances, alleviate muscle soreness, relieve joint stress, and correct soft tissue restrictions (Barnes, 1997; Curran, Fiore, & Crisco, 2008; MacDonald et al., 2013). Since foam rolling has been shown to be an effective tool for recovery, investigators postulated if SMR could be effective during the warm-up process (Boyle, 2009; Clark & Russell, 2009). Another technique that has been shown to increase muscular performance is through WBV.

Traditionally, WBV is achieved by standing on a vibrating platform, which initiates rapid eccentric and concentric contractions. Research suggests that WBV has the ability to improve muscular performance through the activation of the central nervous system, which enhances neuromuscular control (Issurin & Tenenbaum, 1999). While WBV has been shown to be an effective tool to increase power production, it is not widely used in collegiate strength and conditioning because the equipment is large and expensive. This has resulted in the production of a relatively new tool that essentially combines the effects of local muscular vibration and SMR; the vibrating foam roller.

**Problem:**

Vibrating foam roller companies claim to have the ability to penetrate deeper than a traditional foam roller, thus improving blood flow, and increasing range of motion as well as flexibility. Currently, there is limited research concerning SMR as a warm-up tool. The research that has been conducted lacks consistency between studies, primarily the warm-up protocols as well as the foam rollers. There is even less research regarding the effectiveness of vibrating foam rollers. A thesis experiment completed by Bailey (2014) found that vibrating and non-vibrating foam rolling does not provide any significant enhancement in subsequent power production. Typically, in a collegiate strength and conditioning setting, athletes will participate in a more complete warm-up prior to strength training, practice or competition, than the athletes in this study. The purpose of this study was to examine the effect that vibration through SMR in combination with a dynamic stretch routine has on maximum power output. This warm-up design follows the typical order a collegiate athlete would follow.

**Hypothesis:**

$H_0$= There will be no statistically significant difference in the amount of power produced between dynamic stretching alone, non-vibrating self-myofascial release with dynamic stretch, and vibrating self-myofascial release with dynamic stretch conditions.

$H_0$= There will be no statistically significant difference in the height of the vertical jumps between dynamic stretching alone, non-vibrating self-myofascial release with dynamic stretch, and vibrating self-myofascial release with dynamic stretch conditions.

$H_a$= There will be a statistically significant difference in the amount of power produced between dynamic stretching alone, non-vibrating self-myofascial release with dynamic stretch, and vibrating self-myofascial release with dynamic stretch conditions.

$H_{a=}$ There will be a statistically significant difference in the height of the vertical jumps between dynamic stretching alone, non-vibrating self-myofascial release with dynamic stretch, and vibrating self-myofascial release with dynamic stretch conditions.

**Limitations/Delimitations:**

The study was limited to the instruments that were used, specifically the VibraRoller and the Just Jump Mat. The VibraRoller contains a vibrating component for optional use. The study was delimited to 21 participants that consisted of NCAA Division I and Division III female volleyball student-athletes from Eastern Washington University and Whitworth University.

**Assumptions:**

It was assumed that the participants were hydrated, and refrained from ingestion of caffeine or nicotine within 24 hours prior to the test. Participants were questioned upon arrival. If the participants stated that they had ingested caffeine or nicotine within 24 hours of the test they were asked to reschedule the testing day.

**Significance:**

The significance of this study was to clarify if SMR and isolated muscle vibration combined with a dynamic stretch routine was a valid pre-performance technique for power production; to potentially enhance an athlete's performance.

**Summary:**

This chapter provided an explanation of the problem surrounding different type of warm-up protocols and their effectiveness on athletic performance, specifically static and dynamic stretching, SMR, and WBV. This chapter also discussed the proposed benefits vibrating foam rollers may have on an athlete's performance.

**Definition of Terms:**

Active warm-up - increases core temperature, blood flow and prepare the body for exercise though movement (Fletcher & Jones, 2004).

Dynamic Stretch – Controlled movement through the active range of motion for each joint (Fletcher & Jones, 2004).

Foam Roller – Non-compressible cylindrical tube used for self-myofascial release

Self-myofascial release – individuals use their body weight on a myofascial roller to exert pressure on the opposing soft tissues (Curran, Fiore, & Crisco, 2008).

Static Stretch – Moving a limb to its end range of motion and holding the stretched position for 15-60 seconds (Norris, 1999; Young & Behm, 2002)

# Chapter 2

## Review of Literature

In order to prepare for practice, competition, or strength training, athletes use a variety of mental and physical techniques to prime the body for the rigors of the ensuing activity. While mental preparation is important to overall athletic performance, the focus of this study is on physical preparation, specifically using techniques such as dynamic stretches, foam rolling and foam rolling with vibration. Understanding the best way to prepare athletes prior to competition may greatly enhance their ability to perform.

Strength and conditioning coaches regularly lead their teams through a warm-up, and generally follows a typical order. Warm-ups often begin with a low intensity active movements, followed by the stretching of muscles involved in the ensuing activity, and completed by rehearsing specific athletic skills that gradually increase in intensity (Young & Behm, 2002). Active warm-ups are often recommended for optimal performance, because they have been shown to increase muscle temperature (Bishop, 2003). Traditionally, static stretching has been recommended during the warm-up, because it is believed to increase range of motion about a joint, alleviate muscle soreness, reduce the risk of injury, and enhance performance, (Bradley, Olsen & Portas, 2007; Hough, Ross, & Howwatson, 2009; Robbins & Scheurermann, 2008). This has lead researchers to focus on the effectiveness of static stretching as a method to prepare athletes for optimal muscular performance.

### Static Stretching

Static stretching is defined as placing a limb at the end of its range of motion and then holding the stretched position for a period of time usually ranging between 15-60 seconds (Young & Behm, 2002). Although research has not completely ruled out static stretching as a means of warm-up, an increasing amount of research suggests it may negatively affect athletic performance by reducing and athletes ability to execute power (McNeal & Sands, 2003) strength (Samuel et al., 2008) and speed activities (Vetter, 2007). For example, McNeal and Sands (2003) evaluated the effect of static stretching on jump performance in trained girl gymnasts using a drop jump test protocol, and discovered that jumping performance was reduced by 9.6% compared to the control condition. While it is unknown exactly why static stretching may cause a decrease in power, researchers believe that the decreased stiffness of the musculotendinous unit may inhibit the contractile elements in the muscular tissue due to changes in the length-tension relationship (Fowles, Sales, and MacDougall 2000).

While numerous studies have reported a reduction in jumping performance post static stretching, other studies have not (Cornwell, Nelson, & Sidaway, 2002; Knudson, Bennet, Corn, Leick & Smith, 2001; Power, Behm, Cahill, Carroll & Young, 2004; Samuel et al., 2008). It should be noted, however, that a major difference in said studies was that they used untrained populations (Cornwell et al., 2002; Power et al., 2004; Knudson et al., 2001; Samuel et al., 2008). Samuel et al., (2008) found a significant reduction in the amount of power produced, but did not find a reduction in vertical jump height. Samuel et al., (2008) hypothesized that the main difference between vertical jump height and power was technique; that the untrained population may not have been able to reproduce the same jumping mechanics for each jump, as a highly trained subject would be able to. For example, if a person could produce enough power to jump 30 inches, but did not use proper technique, the participant would not effectively utilize the power to maximize their vertical jump height. While multiple studies did not report negative effects on vertical jump height, force, strength, and power following static stretching (Knudson et al., 2001; Power et al., 2004; Cornwell et al., 2002; Samuel et al., 2008), there has not been a study to report a significant increase in vertical jump height. A systematic review by Kallerud and Gleeson (2013) found that approximately half of all the research came to the conclusion that performance was impaired from acute static stretching. The rest of the research reported no significant effect. Since static stretching negatively affects performance, Kallerud and Gleeson recommend that pre physical activity exercises should be focused on dynamic, rather than static stretching due to the potential performance benefits (2013).

**Dynamic Stretching**

A dynamic stretching routine is defined as actively moving joints through an increasing range of motion while increasing the speed of the movement (Christensen & Nordstrom, 2008). Researchers prefer dynamic stretching over static, because it includes movements that are specific to sport or a certain movement pattern (Christensen & Nordstrom, 2008). In contrast to static stretching, dynamic stretching routines have frequently shown significant increases in performance tests that measure vertical jump height, drop jump height, force, and power (Faigenbaum, Bellucci, Bernieri, Bakker, & Hoorens, 2005; Fletcher & Monte-Colombo, 2010; Herman & Smith, 2008; Holt & Lambourne, 2008; Hough et al., 2009; McMillian, Moore, Hatler, & Taylor, 2006; Needham, Morse, Degens, 2009; Ryan et al., 2014). While all studies did not report significantly positive improvements in performance, no studies have reported negative effects on performance (Christensen & Nordstrom, 2008; Dalrymple, Davis, Dwyer, &

Moir, 2010). Dynamic stretching is believed to increase athletic performance through enhanced coordination, increased heart rate, increased core body and muscle temperature, stimulation of the nervous system and post activation potentiation (PAP) (Fletcher, 2010; Herman & Smith, 2008; Jaggers, Swank, Frost, & Lee, 2008; Ryan et al., 2014).

PAP is described as the temporary increase in muscle contractile performance after a previous conditioning contraction (Tillin & Bishop, 2009). Tillin and Bishop believe that PAP could benefit the performance of explosive sports by increasing the rate of force development, and thus mechanical power (2009). Dynamic stretches have the ability to activate a greater number of muscle fibers compared to static stretches, which allows the body to increase its rate of force development. The subsequent rise in force development is suggested to act synergistically with PAP to improve performances related to power production (Sale, 2002). Although studies have not explicitly tested dynamic stretch routines ability to increase PAP, several authors speculate that it may have played a role in the outcome of their study (Chaouachi et al., 2001; Faigenbaum et al., 2005; Fletcher, 2010; Hough et al., 2009; McMillian, 2006). Sale (2002) hypothesized that the rehearsal of a skilled movement, much like dynamic stretching, may have the ability to condition the muscles to contract more forcefully.

Fletcher's research compared three different warm-up protocols that began with a 10 minute jog and were followed by either (1) no stretching, (2) slow dynamic stretching at 50 beats per minute or (3) fast dynamic stretching at 100 beats per minute. Fletcher's experiment revealed that the fast dynamic stretching condition had a significant increase in jump performance over the slow stretching and the no stretching conditions. The increase in performance associated with PAP has been traditionally linked to maximal contractions prior to performance, but it can also be caused by submaximal priming exercises (Ce, Rampichini, Maggioni, Veicsteinas, & Merati, 2008). Research has shown that dynamic stretching generally leads to increased performance, making it the recommended method to prepare the body for physical activity and sport.

Dynamic stretching is widely used in athletics because it mimics movements that are related to sport, while simultaneously preparing the athlete's body for practice or strength training sessions. Collegiate strength and conditioning coaches utilize active dynamic movements in preparation for strength training because of these potential performance benefits. Regular training and participation may cause microtrauma. Microtrauma initiates an inflammatory response that may lead to fascial scar tissue and other muscular dysfunctions over time (Curran, Fiore, & Crisco, 2008). Curran et al. describes fascia as being a sheet of connective tissue that covers and binds the body's soft tissue together (2008). As a result of dehydration and muscular injuries, fibrous adhesions can develop, which could prevent normal joint mechanics due to the loss of fascial extensibility (Curran, Fiore, & Crisco, 2008; MacDonald et al., 2013). Recently, a relatively new technique known as self-myofascial release (SMR) has been used to treat these myofascial restrictions.

**Self-Myofascial Release**

In addition to active dynamic stretching routines, many strength and conditioning coaches have their athletes "roll out," by utilizing foam rollers as a method of SMR. Foam rolling can be considered a form of self-induced massage because the pressure that the roller exerts on the muscles resembles the pressure exerted on the muscle through manual manipulations by a massage therapist. Athletes use their body weight to exert pressure on the soft tissue, using both direct and sweeping pressure, which generates friction between the tissue and the foam roller. (Curran et al., 2008; Healey, Hatfield, Blanpied, Dorfman, & Riebe, 2013; Pearcey et al., 2015). Fascial restrictions often occur in response to injury, disease, inactivity, or inflammation, which cause the fascial tissue to lose its elasticity and become dehydrated (MacDonald et al. 2013). Muscular imbalances, the over recruitment of muscle fibers, overworked muscles, and recurring micro-trauma all contribute to fascial restrictions (Behara & Jacobson, 2017). Restrictions stimulate the development of inelastic, fibrous adhesions, and prevent normal muscle mechanics that consist of joint range of motion, muscle length, decreases in strength and soft tissue extensibility (MacDonald et al., 2013; Curran, Fiore, & Crisco, 2008). Foam rolling, when applied to the soft tissue, is thought to warm the fascia, and allow for fibrous adhesions to break up (MacDonald et al., 2013). Other responses include the restoration of soft tissue, increased nitrogen dioxide, and improved vascular plasticity (Peacock et al. 2014). The ability foam rolling has to dissipate fibrous adhesions, and improve movement, in theory, could allow athletes to have a more effective dynamic warm-up (Boyle, 2009; Clark & Russell, 2009).

Currently, very few research articles have examined the effects of foam rolling prior to performance testing (Bailey, 2014; Behara & Jacobson, 2017; 2013; Healey et al., 2013; Jones et al., 2015; MacDonald et al., 2013; Peacock et al., 2014). These studies have examined flexibility, force, power, strength, agility, as well as vertical jump height and have generally come to the conclusion that foam rolling prior to maximal testing does not result in any significant increases in athletic performance. For example, Healey et al., (2013) compared the effect of acute foam rolling on a specific muscle group for 30 seconds to a series of planking exercises, which resembled the position used for foam rolling and found there to be no significant increase in performance following the foam rolling protocol. While the majority of studies have not found foam rolling to be effective in improving vertical jump performance, others have.

Peacock et al., found a significant increase in performance after foam rolling using a population that had experience in professional, or collegiate athletics (2014). The subjects acted as their own control, and tested a variety of athletic measures after completing a dynamic stretch routine. In the experimental trial condition an acute bout of foam rolling was completed prior to the dynamic stretch routine. Significance was found in the vertical jump, the standing long jump, the pro agility test, and the one rep max bench press. The only variable in which there was not a significant increase was in the sit-and-reach flexibility test (Peacock et al., 2014). This study showed that in an athletically trained population foam rolling can result in a significant improvement in strength, speed, agility and jumping ability. While foam rolling is an effective tool to help relieve fascial restrictions that may be limiting muscle and joint range of motion, whole body vibration (WBV) is becoming increasingly popular because of its ability to improve muscular performance (Cochrane, Stannard, Sargeant, & Rittweger, 2008).

**Whole Body Vibration**

Traditionally, WBV is achieved through standing on a commercially manufactured machine with an oscillating platform, which moves in the vertical plane, or tilts up and down about the central axis. The machine produces vertical sinusoidal vibrations indirectly to the body using a low vibration frequency (Cochrane, Stannard, Sargeant, & Rittweger, 2008). Research suggests that WBV has the ability to improve muscular performance through the activation of the central nervous system, and enhanced neuromuscular control (Issurin & Tenenbaum, 1999). Improved athletic performance through WBV may be due to its ability to increase motor unit synchronization, improve stretch reflex potentiation, and lead to synergistic muscle activity as well as the inhibition of antagonist muscles (Bullock et al., 2008). This may be initiated from rapid eccentric and concentric contractions, which in turn evoke increased muscular work, resulting in an elevated metabolic rate (Cochrane et al., 2008). The tonic vibration reflex (TVR) is a response elicited when vibration is applied directly to a muscle belly or tendon (Eklund & Hagbarth, 1966; Cormie, Deane, Triplett, & McBride, 2006). This reflex is characterized by activation of muscle spindles predominantly through Ia afferents, and activation of extrafusal muscle fibers through α-motor neurons (Cormie et al., 2006). The use of vibration on an active muscle has recently been shown to cause a shift in electromyographic patterns (Issurin, Liebermann, & Tenenbaum, 1994). Research has also shown that vibration stimulates transient increases in specific hormones, such as growth hormone and IGF-I (Bosco et al., 2000). This has lead researchers to conclude WBV is an effective form of warm-up, because it leads to an increase in maximal muscular performance, specifically in the vertical jump test.

A study completed by Cormie et al., (2006) showed that a 30 second bout of WBV resulted in a significantly higher vertical jump height when compared to standing on the vibration platform without any vibration using moderately resistance trained males. Although a significant increase was observed, it was slight (.7%). Torvinen et al., (2002) found a 2.2% increase in jump height using a single four minute bout of WBV, while Bosco et al., (2000) observed a 3.9% increase using 10 bouts of 60 seconds. These results suggest that WBV may be a reasonable warm-up procedure, but the optimal dose of vibration is still uncertain (Cormie et al., 2006).

Studies completed by Cochrane et al., (2004), and Issurin and Tenenbaum (1998) suggest that a vibratory stimulation has a greater effect on athletes than non-athletes. Issurin and Tenenbaum discovered a significant difference in muscle response between elite and amateur athletes (1998). Both studies support the view that elite athletes have a higher level of central nervous system and muscle receptor sensitivity, making them more receptive to vibration training. If true, the use of WBV as part of a warm-up routine should strongly be considered in athletics. The goal of any warm-up is to prepare athletes and give them the greatest chance of having a successful performance. Power has been shown to be a large determinant in an athlete's ability to be successful, and it is important that the warm-up does not prevent an athlete from developing maximal power.

**Power in Athletics**

Sport is comprised of movements that require the athlete to produce a large amount of force over a short period of time (McBride, Triplett-McBride, Davie & Newton, 1999). Being able to produce the greatest amount of power in the least amount of time is often the main determinant of success (Haff, Whitley & Potteiger, 2001). The ability to produce maximal power is influenced by the type of muscle action involved, the time available to develop force, the muscles ability to store and utilize of elastic energy, and the potentiation of contractile filaments as well as stretch reflexes (Cormie, McGuigan, & Newton, 2011). One component of a muscle's capacity to produce power is known as the force-velocity relationship. During a concentric muscle action, the force and velocity of the movement is described as having an inverse relationship. For example, as the velocity of the concentric muscle action is increased, less force can be generated during that contraction and visa-versa (Cormie et al., 2011). Because the amount of force generated by a muscle depends on the number of attached cross bridges, power is maximized when force and velocity are produced at submaximal values (Lieber, 2002). Another component that is significant in a muscles ability to produce power is the length-tension relationship.

The ability of a skeletal muscle to generate force is critically dependent on the length of the sarcomere (Lieber, Loren, & Friden, 1994). The ‘optimal length’ of a muscle is said to be at rest, because it allows for the greatest potential for force production since there is optimal overlap between actin and myosin fibers (Baechle, Earle, 2008; Lieber et al., 1994). Close (1972) found that resting muscle lengths are slightly shorter than the optimal length. Therefore, muscular force may be increased with a slight stretch prior to activation. While muscular power is defined by the force-velocity relationship, the length-tension relationship influences the ability of muscle fibers to develop force and therefore, play an important role in the production of maximal muscular power (Cormie et al., 2011). Muscle function is necessary for natural human movements and sports requiring the combination of eccentric, isometric and concentric contractions. The combination of contractions is known as the stretch shortening cycle (SSC) (Komi, 1986). The eccentric action during a SSC allows time for the agonist muscles to develop force prior to the concentric contraction (Cormie et al., 2011). When an active muscle tendon unit is stretched it stores mechanical work, and can also be stored as potential energy in the series elastic component (SEC) (Cavagna, Saibene, Margaria, 1965; Cavagna, Dusman, Margaria, 1968). The recoil of the SEC is believed to contribute to the increased force at the beginning of the concentric phase of the SSC, ultimately leading to maximal power production (Bosco & Komi, 1979; Asmussen et al., 1974). If all parts of the warm-up deliberately intend to increase an athlete's power output, that athlete will be set up for the greatest chance of success.

**Conclusion**

In conclusion, it is clear that the best way to prepare athletes for athletic performance has yet to be discovered. This literature review has demonstrated a variety of methods that have been traditionally used to increase the ability for an athlete to produce power. Compared to other methods, acute bouts of foam rolling in combination with vibration could represent a superior method of pre-exercise preparation.

# Chapter 3

# Methods

## Introduction

The purpose of this study was to examine the effect vibration through self-myofascial release (SMR) in combination with a dynamic stretch routine has on maximum power output. This chapter discusses the participants, experimental design, and an explanation of the warm-up protocol, the vertical jump test, and the statistical analysis.

## Participants

Twenty-One NCAA Division I and Division III student-athletes agreed to participate in this research study. The participants were made up of both Eastern Washington University's, and Whitworth University's Varsity Volleyball teams. The research design was a randomized crossover design in which all participants served as their own control by completing all three warm-up interventions that consisted of a dynamic stretch routine alone (DS), non-vibrating foam rolling plus dynamic stretch (NVFR), and vibrating foam rolling plus dynamic stretch (VFR). The subjects were free of any injury that could hinder their individual jump performance at the time of testing. The subjects were actively participating in the team's off-season strength training program at the time of the study.

## Experimental Approach

Before the study was conducted, approval from Eastern Washington University's Institutional Review Board was obtained. Upon approval, subjects were asked to participate in the study. During the familiarization session, the primary investigator explained the subject's role in the study, specifically the aims, benefits, and potential risks participation in the study may contain. An informed consent document was signed by those willing to participate in the study. The subjects were then randomly placed in the order in which each participant completed the three warm-up protocols. After the informed consent document was received, the order was established, the demographic information was recorded, and the foam rolling and dynamic stretch protocol were described. The subjects were asked to refrain from caffeine and nicotine 24 hours prior to testing. Subjects were also tested at the same time of day to reduce within subject variation.

On each of the three testing days, the participants completed one of the following conditions (dynamic stretching (DS), non-vibrating foam rolling plus dynamic stretch (NVFR), and vibrating foam rolling plus dynamic stretch (VFR)), which was immediately followed by a countermovement vertical jump. The warm-up conditions that involved foam rolling were completed prior to the dynamic stretch routine. Either foam rolling procedure was completed using the vibrating foam roller. Unless the foam rolling procedure required vibration the foam roller remained off. The foam rolling procedure followed Peacock et al., (2014), which was found to significantly increase a variety of athletic performance tests. The foam rolling procedure primarily targeted the lower extremities musculature, specifically the gluteus region, hamstring region, calves, and quadriceps, as well as the thoracic and lumbar regions of the spine. Each region was rolled at a pace of five strokes over the length of the area over the course of 30 seconds. Each exercise was performed bilaterally. Immediately following the foam rolling protocol, the participants were instructed through the dynamic stretch routine.

The dynamic stretch routine followed Ryan et al., (2014), which found a significant increase in vertical jump height following the dynamic stretch routine. The dynamic stretch routine in this experiment began with low intensity movements and progressively increased to high intensity movements with a 15 second rest period between each exercise. Per recommendation of the National Strength and Condition Association, each exercise will be executed in a controlled manner through a range of motion required in many team sports (Baechle & Earle, 2008). Low intensity exercises (Table 1 a-c) were completed with four repetitions on each leg at a walking pace. Moderate intensity exercises (Table 1 d-h) were completed with five repetitions on each leg at a slightly quicker pace. High intensity exercises (Table 1 i-k) were completed with six repetitions on each leg at a rapid pace. Each of the dynamic stretch exercises is described in greater detail in Table 1. After the assigned warm-up was completed for that day, the participants immediately performed the maximal vertical jump test.

The vertical jump test was completed using a Just Jump Mat. The Just Jump Mat calculated the height of the vertical jump using a kinematic equation that determined jump height by flight time (Leard et al., 2007). Research has found the Just Jump Mat to be a reliable test for measuring jump height (Nuzzo, Anning, & Scharfenberg, 2011), and also more efficient than a jump-and-reach or belt tests because there is no need to measure the height of reach and no need to perform calculations to derive the height of the jump (Isaacs, 1998). The subjects were asked to place both feet in the middle of the Just Jump Mat, drop their hips to a depth they feel would maximize their jump height and explosively jump as high as possible using their arms as they would in a volleyball match. The subjects testing together rotated after each jump, and also were given one minute between attempts to allow for recovery to maximize performance. The subjects were given one practice attempt and was followed by three maximal recorded attempts. The mean of the three jumps was used to calculate the vertical jump height for each condition. Any jump that fell outside the coefficient of variation of <3% was removed from the data. The coefficient of variation for vertical jump performance was previously established by Hough, Ross, & Howatson, (2009) and Moir, Glaister, & Stone, (2004). The mean height of the jumps were used for calculating the power output using the Sayer's Equation (Watts = 60.7 *Jump Height (cm) + 45.3 * Body Mass (kg) – 2055) and was used for statistical analysis.

Table 1.

| Exercises | Execution |
|---|---|
| **Low Intensity** | **Exercises performed at a slow walking pace.** |
| a. Walking Knee Pull | While walking forward, pull right knee, then left knee to chest with both hands. |
| b. Walking Quad Stretch | Grab foot, pulling heel toward the glutes. Let go of foot while stepping forward. Perform same movement for opposite leg. |
| c. Walking Leg Cradle | Grab foot, bringing heal across body toward opposite hip. Let go of foot while stepping forward. Perform same movement for opposite leg. |
| **Moderate Intensity** | **Exercises performed at a walking pace.** |
| d. Forward Gate Swings | While walking forward, raise right leg the left leg up and over an imaginary gate |
| e. Straight Leg March | While walking forward, raise extended right leg and touch the palm of the left hand and return to ground. Repeat each side. |
| f. Forward Lunge with Opposite Arm Reach | Lunging forward with right leg, while simaltaneously reaching overhead with opposite arm. Repeat for each side. |
| g. Forward Lunge Elbow to Instep | Lunging forward with the right leg, dropping the right elbow reaching for the instep of the right foot. Repeat for each side |
| h. Lateral Lunge | Lunge to the side while maintaining torso in an upright position. |
| **High Intensity** | **Exercises performed at a fast jogging pace.** |
| i. High Knee Run | Raise the right knee, then the left knee, to chest level while running forward. |
| j. Running Heel Kick | Rapidly kick heels toward buttocks while moving forward. |
| k. High Knee Skip | While skipping, emphasize height, high knee lift and arm action. |

## Statistical Analysis:

All statistical analyses were conducted using SPSS version 24. Descriptive statistics of all variables were determined including age, height, weight, vertical jump height and power. A repeated measures ANOVA was conducted to determine whether there was a significant difference between the three warm-up conditions (DS, NVFR, and VFR). The Alpha level was set at $p \leq .05$. If significant differences were found, a pairwise comparisons test was run to determine which condition differed significantly. An independent samples t-test was also conducted to determine if NCAA Division had a significant impact on the effectiveness of the vibrating foam rolling protocol.

**Summary:**

This chapter provided a description of the methodology used for this study as well as the experimental design, participants, procedures, and statistical analysis used.

# Chapter 4

# Results

## Introduction

The purpose of this study was to examine if vibration combined with self-myofascial release (SMR) would affect a female athlete's ability to maximally produce power. The research null hypotheses stated that there would be no statistically significant difference in the amount of power produced or vertical jump height between dynamic stretching alone, non-vibrating self-myofascial release with dynamic stretch, and vibrating self-myofascial release with dynamic stretch conditions.

## Demographics

Twenty-One healthy collegiate female volleyball players volunteered to participate in the study. Nine participants currently play at the Division I level, while the other 12 currently play at the Division III level. Descriptive variables, which were recorded at the initial meeting, included age (19.90±1.18 years), weight (73.63±8.95 kg), and height (173.48±7.09 cm).

## Descriptive Statistics

Descriptive statistics were computed for jump height in the vibrating foam roll plus dynamic stretch (V) condition (52.09±5.27 cm), non-vibrating foam roll plus dynamic stretch (NV) condition (51.87±5.92 cm), and dynamic stretch (D) alone condition (51.23±5.10 cm), and for jump power in the V condition (4443.14±535.10 W), NV condition (4429.31±580.09 W), and D condition (4390.03±497.37 W). Descriptive statistics are summarized in the Table 2.

**Repeated Measures ANOVA**

For all measures analyzed, Shapiro-Wilk tests returned p-values greater than 0.05, indicating that the data was not significantly different from a normal distribution for any measure. For all ANOVA's, Mauchly's Tests of Sphericity returned p-values greater than 0.05, indicating that the assumption of sphericity was met in all cases. Based on the results of these tests, the proper assumptions were met for all repeated measures ANOVA's performed in this study and no adjustments were necessary to proceed. This study found no significant difference between jump height between the warm-up condition ($F(2,40)=1.705$, $p=0.195$, $\eta_p^2=0.079$), therefore the null hypothesis for jump height was not rejected. Likewise, this study found no significant difference between jump power between the warm-up condition ($F(2,40)=1.754$, $p=0.186$, $\eta_p^2=0.081$), therefore the null hypothesis for jump power was not rejected. A repeated measures ANOVA did, however, indicate a significant difference in the perceived effectiveness of the warm-up due to the warm-up condition ($F(2,40)=5.043$, $p=.011$, $\eta_p^2=0.201$, CI=[0.213,1.120]). Pairwise comparisons showed that subjects perceived the vibrating foam rolling with dynamic stretch condition significantly more effective than only a dynamic stretch condition ($p=0.003$). No other pairwise comparison between VFR, NVFR, and DS conditions showed significance. Repeated measures ANOVA results for both dependent variables (jump height and jump power), as well as repeated measures ANOVA results for warm-up condition perceived effectiveness are summarized in the Table 2.

Table 2

| VARIABLE | F | p | $\eta_p^2$ | CI-95% | CI+95% |
|---|---|---|---|---|---|
| 1. Warm-Up on Jump Height | 1.705 | 0.195 | 0.079 | | |
| 2. Warm-Up on Jump Power | 1.754 | 0.186 | 0.081 | | |
| 3. Perceived Effectiveness of Warm-Up | 5.043 | 0.011 | 0.201 | 0.213 | 1.120 |

**Independent Samples T-Test**

An independent samples t-test was run to separate the participants by their respective division (NCAA Division I vs. Division III). The results showed that there was no significant difference in jump height or power between divisions for any of the treatments examined.

**Summary**

This chapter presented a description of the statistical analysis used in this study. The descriptive variables as well as the results of the repeated measures ANOVA were presented.

# Chapter 5

# Discussion

## Introduction

The purpose of this study was to examine the effect vibration through self-myofascial release in combination with a dynamic stretch routine has on maximum power output. Within this chapter we will discuss, 1) the primary findings of this research and how they compare to what we already know about the effects of vibration, 2) the implications of those findings, 3) the recommendations for future research, and 4) the conclusions of the chapter and overall research.

## Primary Findings

The present study demonstrated that vertical jump height and vertical jump power are not significantly improved after a bout of foam rolling with vibration combined with dynamic stretch compared to foam rolling without vibration combined with dynamic stretch or dynamic stretching alone in collegiate volleyball players. These results demonstrate that neither vibrating nor non-vibrating foam rollers resulted in a significant positive effect on a collegiate female volleyball player’s ability to produce power. This study also indicates that any form of foam rolling prior to a dynamic warm-up may not be necessary to achieve optimal performance in power-based activities. While the vibrating protocol did not significantly affect vertical jump height or power, the post questionnaire revealed that participants felt that the vibrating foam rolling protocol better prepared them for the vertical jump test, compared to the other two warm-up conditions. In evaluating raw numbers, while not statistically significant, the mean improvement in jump height and power was higher with the use of the vibrating foam rollers.

**Implications**

The results of this study were somewhat similar to a thesis research experiment completed by Bailey (2014). Similar to the present study, Bailey (2014) found no significant difference between vibrating foam rolling and foam rolling on vertical jump height. However, unlike the present study, Bailey found that the vibrating foam roller produced the lowest peak power output of the three conditions. Bailey (2014) did not include a dynamic warm-up following their bout of foam rolling which perhaps could explain these small differences. To date, that is the only other study evaluating vibrating foam rollers and their ability to affect vertical jump height and power.

Other studies have also not demonstrated a significant effect of foam rolling on vertical jump performance. For example, Healey et al., (2013) evaluated vertical jump height and power following a foam rolling protocol or a planking protocol that utilized positions mimicking those used in the foam rolling protocol without incorporating a foam roller, thereby serving as a control condition. The participants performed a dynamic warm-up prior to the foam rolling or planking protocols, which was in reverse order of the present study. The participants were then tested in the vertical jump. While Healey et al., (2013) found that vertical jump height was slightly higher following the foam rolling trial, and vertical jump power was slightly increased following the planking trials, ultimately, there was no significance in vertical jump height and vertical jump power between either warm-up protocols.

In a recently published research article, Behara and Jacobson (2017) were unable to find significance in peak and average vertical jump power, as well as peak and average vertical jump velocity compared to the baseline assessment. While the results were not significant, Behara and Jacobson observed the foam rolling protocol to have the highest means in both peak and average vertical jump power and velocity. Behara and Jacobson utilized a more aggressive foam roller (The Rumble Roller), which was equipped with raised nodules that allegedly act upon and stimulate deeper layers of muscle tissue, and also stretch the muscle and fascia in multiple directions. Behara and Jacobson's foam rolling protocol consisted of rolling each extremity unilaterally for 1 minute each, totaling 8 minutes in duration. The amount of time spent foam rolling was almost twice as long as the current study (8 minutes vs. 4.5 minutes). This study did not explain exactly what the dynamic stretch procedure consisted of, but they did explain that the dynamic stretch protocol consisted of stretching slowly and under control to avoid a bouncing motion of the same muscles as those involved in the foam rolling protocol. Although the foam rolling time was much longer and they used a much different foam roller, their findings of no statistically significant differences in producing power were similar to our results.

Having used the same foam rolling protocol from Peacock et al. (2014), this would easily be the most comparable to the current study. The main difference between the two studies was the addition of the vibrating foam rolling protocol. Peacock et al., had participants complete two separate experimental trial conditions. In the first condition, the participants were taken through a variety of dynamic movements, while the other condition took the participants through a bout of foam rolling prior to the same dynamic stretches (2014). Unlike the current study, Peacock et al., found significance, suggesting that a warm-up combined with a series of foam rolling techniques has the potential to improve power, speed and agility performance test results (2014). This specific warm-up consisted of lower body movements (squat jumps, sprinting high knees, sprinting butt kicks, alternating lunge jumps, alternating log jumps), but did not incorporate movements to properly mobilize and prepare the tissues for the vertical jump test. For example, Holt and Lambourne (2008) define dynamic stretching as the execution of "movements that take the limb through the range of motion by contracting the agonist muscle, allowing the antagonist muscle to relax and elongate." Although this warm-up, by definition, fails to properly prepare the body for activity, it does however satisfy the requirement of specificity and potentiation set forth by the National Strength and Conditioning Association (Baechle & Earle, 2008). By finding significance, Peacock et al., (2014) has shown that a warm-up that is considered atypical, may be better at preparing athletes for the vertical jump test. The current study (which utilized a more extensive, and likely better optimized, jump-specific dynamic warm-up) found no significant differences between those two conditions.

While the current study did not find vibrating foam rolling to have a significant effect on power production or jump height, whole-body vibration training techniques have been effective. The slight overall improvement shown in this study may indicate that what we are lacking is the optimal dose of vibration and/or the optimal placement in the warm up routine, to prepare athletes for peak performance. It could be possible that the frequency of the vibratory stimulus generated by the vibrating foam roller was not enough to produce a significant effect on vertical jump height. Another potential reason for the lack of significance may be due to the order of the warm-up conditions. Ekund and Harbarth (1966) explain that stretched muscles are more sensitive to vibratory stimulation and contract stronger. Although this would not follow the typical order in which warm-ups are generally designed, completing a dynamic warm-up prior to a session of vibrating foam rolling may lead to different results. Issurin and Tenebaum (1998) found that the difference in a muscles ability to produce power between elite and amateur athletes was statistically significant, stating that the average gain in maximal power owing to vibratory stimulation was greater amongst elite athletes when compared to amateurs. The researchers believed these results were due to the higher sensitivity of muscle receptors and central nervous system of elite athletes to additional stimulation (1998). While this may be the case in certain situations, the current study's results are not in agreement. An independent samples t-test revealed that neither jump height nor power was significantly different between divisions for any of the treatments examined. The subjects used in this study may be closer in overall athletic ability than their respected divisions suggest. Comparing a NCAA Division I top 25 volleyball school to a lower Division school may find results that agree with Issurin and Tenebaum (1998).

**Recommendations for Future Research**

Future research is obviously needed in this area. It would especially be helpful to add a group that does not perform a warm-up. Originally, it was decided against including a no warm-up condition, because that is rarely used in an athletic setting. However, it is conceivable that a no warm-up condition may lead to the best results in vertical jump height or power compared to the other examined warm-up conditions. Another change that could lead to different results would be to test the subjects during a different part of the year. This study ended up being completed during each team's spring season, during which the athletes were participating in practice multiple times a week. Over the course of the testing week, the primary investigator overheard the participants express how sore or tired they were due to practice. When using collegiate athletes as subjects, there is generally never a time in which they are without athletic obligations whether it be strength training, practice, competition, or all of the above. The best time to complete a study of this nature may be at the end of winter, during the off-season when the athlete's only obligation is strength training, or at the beginning of the regular season, right before the initiation of fall camp. For example, Behara and Jacobson completed their study in the athlete's respected off-season (summer). If completed at one of the listed times of year, the athletes may be more "fresh" and not fatigued from other athletic obligations.

Based on the results of this study, future research should examine vibrating foam rollers that offer a range in the frequency of vibration. By examining a range of vibratory frequencies on foam rollers, research may be able to determine if an optimal frequency exists for increasing muscular performance. Ronnestad (2004) believes it is possible that the ideal vibration period to achieve acute strength/power gains is individual, thus fatigue may explain why some studies have not been able to find positive effect after one acute bout of vibration.

**Summary**

In summary, vibrating as well as non-vibrating foam rollers do not significantly increase an athlete's ability to produce power when followed by a dynamic stretch routine. However, participants reported that they believed the vibrating foam rolling protocol better prepared them for the vertical jump test, and there were small improvements (but not statistically significant) in mean jump height and power following the VFR condition. This chapter provided an overview of the current study as well as a review of the previous research that focused on foam rolling as a tool to enhance athletic performance. It is clear that more research needs to be completed in this area before any claims can be made in favor of or against foam rolling as a preparation tool.

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# Appendix A

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**Consent Form**
**The Acute Effect Vibrating Foam Rollers have on the Lower Extremities Ability to Produce Power**

Jared Klingenberg, Graduate Student, Physical Education Department, (206) 354-8516
Garth Babcock, Athletic Training Program Director, Physical Education Department, (509) 359-2427

**Purpose and Benefits**

The purpose of this study is to find if vibrating foam rollers are an effective way to increase an athlete's ability to produce power. The data this study will provide is important for strength and conditioning coaches as well as athletes as the ability to produce power is a factor of athletic ability. This study will further satisfy the Physical Education Graduate Department at Eastern Washington University graduation requirements.

**Procedures**

As subjects you will be given a 2-digit number that will be used to track your data throughout the study. You will be asked to complete three separate warm-up routines on three separate days. The warm-up routines will consist of (a) dynamic warm-up, (b) non-vibrating foam rolling plus dynamic stretch routine, or (c) vibrating foam rolling plus dynamic stretch routine. You will be assigned to one of these routines each day. Once the random order is decided upon, you will schedule time slots that will allow you to complete each warm-up condition at the same time each day. After the informed consent document is received, and the order is established, the demographic information (height, weight, and age) will be recorded, and the foam rolling and dynamic stretch protocol will be described. Each testing day must be separated by at least 48 hours. Upon arrival, you will be taken through one of the three warm-up routines that you are scheduled for that day. After completing the selected warm-up routine, you will be tested in the vertical jump. For the vertical jump you will use a countermovement technique in which you will flex your hips, knees and ankles before jumping for maximal height. You will also be allowed to use arm swing as you would during a volleyball match. The vertical jump height will be measured using a Just Jump Mat. The Just Jump Mat measures the height of the jump by the amount of time spent in the air. You will be given three jump attempts. After completing the jump attempts, you will be asked to complete a follow-up questionnaire (attached). It is important to understand that you are free to not answer any questions which you find objectionable. Each testing session will take approximately 20 minutes to complete, or one-hour in total time commitment.

**Risk, Stress or Discomfort**

Maximal effort testing carries inherent risks such as joint or muscle damage, and general soreness. The risks involved, however, are no greater than a general practice or game.

**Other Information**

There are no alternative procedures. Your identity will remain confidential. Your coaches will only be given averaged team data upon request. Participation in this study will not affect playing time in any form. If at any time you do not wish to continue participation in the study you may withdraw without penalty.

_______________________________________________

Signature of Principal Investigator Date

"The study described above has been explained to me, and I voluntarily consent to participate in this research study. I have also had an opportunity to ask questions." I understand that by signing this form I am not waiving my legal rights. I understand that I will receive a signed copy of this form.

_______________________________________________

Signature of Subject Date

If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protections Administrator, at (509) 359-7971 or rgalm@ewu.edu

Appendix B

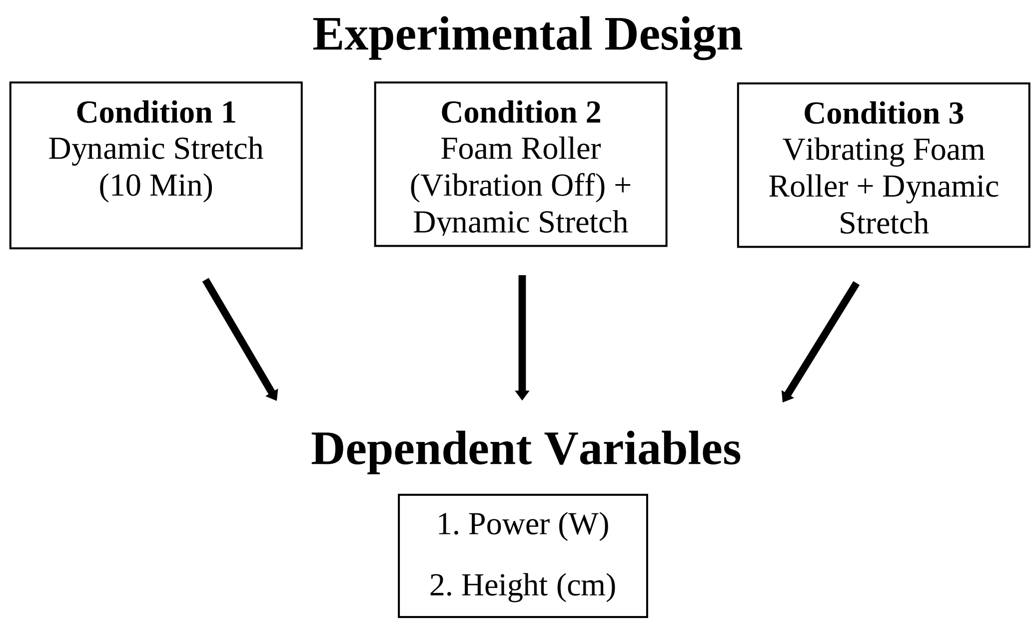


Figure 1.

# VITA

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2015-2017