Eastern Illinois University
The Keep

Masters Theses | Student Theses & Publications

2015

Influence of Various Pre-Exercise Routines on Vertical Jump Performance

Vladislav Milanovic

This research is a product of the graduate program in Kinesiology and Sports Studies at Eastern Illinois University. Find out more about the program.

The Graduate School

EASTERN ILLINOIS UNIVERSITY™

Thesis Maintenance and Reproduction Certificate

FOR: Graduate Candidates Completing Theses in Partial Fulfillment of the Degree
Graduate Faculty Advisors Directing the Theses

RE: Preservation, Reproduction, and Distribution of Thesis Research

---

Preserving, reproducing, and distributing thesis research is an important part of Booth Library's responsibility to provide access to scholarship. In order to further this goal, Booth Library makes all graduate theses completed as part of a degree program at Eastern Illinois University available for personal study, research, and other not-for-profit educational purposes. Under 17 U.S.C. § 108, the library may reproduce and distribute a copy without infringing on copyright; however, professional courtesy dictates that permission be requested from the author before doing so.

Your signatures affirm the following:

- The graduate candidate is the author of this thesis.
- The graduate candidate retains the copyright and intellectual property rights associated with the original research, creative activity, and intellectual or artistic content of the thesis.
- The graduate candidate certifies her/his compliance with federal copyright law (Title 17 of the U. S. Code) and her/his right to authorize reproduction and distribution of all copyrighted materials included in this thesis.
- The graduate candidate in consultation with the faculty advisor grants Booth Library the non-exclusive, perpetual right to make copies of the thesis freely and publicly available without restriction, by means of any current or successive technology, including by not limited to photocopying, microfilm, digitization, or internet.
- The graduate candidate acknowledges that by depositing her/his thesis with Booth Library, her/his work is available for viewing by the public and may be borrowed through the library's circulation and interlibrary loan departments, or accessed electronically.
- The graduate candidate waives the confidentiality provisions of the Family Educational Rights and Privacy Act (FERPA) (20 U. S. C. § 1232g; 34 CFR Part 99) with respect to the contents of the thesis and with respect to information concerning authorship of the thesis, including name and status as a student at Eastern Illinois University.

I have conferred with my graduate faculty advisor. My signature below indicates that I have read and agree with the above statements, and hereby give my permission to allow Booth Library to reproduce and distribute my thesis. My adviser's signature indicates concurrence to reproduce and distribute the thesis.

[redacted]

[redacted]

Printed Name

MASTERS of SCIENCE IN KSS

Graduate Degree Program

20 AUG, 2015

Date

Please submit in duplicate.

Influence of Various Pre-Exercise Routines on Vertical Jump Performance

(TITLE)

BY

Vladislav Milanovic

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2015

YEAR

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

[redacted] /20/15 ATE

[redacted] 8-20-15

DEPARTMENT/SCHOOL CHAIR OR CHAIR'S DESIGNEE — DATE

08/20/15 ATE

THESIS COMMITTEE MEMBER — DATE

/20/15 ATE

THESIS COMMITTEE MEMBER — DATE

ABSTRACT

The purpose of this study was to determine and compare the influence of three different pre-exercise routines (jogging, proprioceptive neuromuscular facilitation in addition to jogging (PNFJ), and whole body vibration (WBV)) on vertical jump (VJ) performance. Twelve physically active, collegiate males between the ages of 18-24 years were recruited to participate. The subjects performed four VJ tests on four nonconsecutive days with a control VJ being performed on the first day and the three remaining VJ performed after each of the pre-exercise routines that were conducted in random order. The jogging pre-exercise routine lasted 5 minutes at light to moderate intensity of 11-13 on a 6-20 RPE scale). The PNF pre-exercise routine consisted of 10 seconds of maximal isometric contraction of the hamstring muscles followed by relaxation and 10 second passive stretch. The WBV pre-exercise routine was performed on a vibration plate in a half squat isometric position for 30 seconds with a frequency of 50 Hz. For each VJ test, three counter movement jumps (CMJ) were performed. Each CMJ was performed at 15 seconds, 75 seconds, and 135 seconds following each of the pre-exercise routines. The highest CMJ jump was recorded as the VJ for that test. There were no significant differences in VJ performance following jogging, PNF, and WBV routine when compared to the control condition. There were also no significant differences between VJ following the jogging and WBV pre-exercise routines. However VJ performance was significantly higher following jogging ($p < 0.018$) and WBV ($p < 0.042$) pre-exercise routines compared to PNFJ.

ACKNOWLEDGEMENTS

There are a few people I would like to thank for their help and support during this project. First, a very big thank you to Dr. John Emmett for his timely revisions involved in the writing process along with constant encouragement. I would also like to thank Dr. Pritschet and Dr. Kattenbraker, members of my committee, for their help and support.

I would also like to thank the Department of Kinesiology and Sport Studies at Eastern Illinois University that made this project possible.

Most importantly, thank you to my mother, Olivera Milanovic. Thank you for making my dreams come true and providing me with unconditional love and support at all times. Without you I would never have come this far. I am grateful for having you in my life and will forever be indebted to you.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Over years of training to enhance athletic and physical performance there have traditionally been various pre-exercise routines, generally called warm-up that precede the main activity itself. These routines have been used in order to prepare an individual for the following physical activity with the intent to reduce the chance of injury, improve physical performance or both (American College of Sports Medicine, 2011).

Although different types exist, a pre-exercise routine usually consists of minimum of five to ten minutes of low to moderate level intensity activity (ACSM, 2013). One purpose of a pre-exercise routine is to increase the temperature and blood flow to the muscles and therefore prepare individual's body for exertion coming with exercise or sports competition. In addition, pre-exercise warm-up increases blood flow and oxygen distribution from the cardiopulmonary system and therefore prepares individual's body for exercise (ACSM, 2011). The general belief is that a good pre-exercise routine protocol should include body segments and muscles that are going to be used during exercise and that it should mimic the intended activity to a certain extent.

This study investigated three pre-exercise routines: jogging, proprioceptive neuromuscular facilitation in addition to jogging (PNFJ), and whole body vibration (WBV). Out of these three routines, jogging is the most common while the later two, especially WBV, are popular in sport populations and a few exercise knowledgeable individuals who want to increase their performance. All three of these work in different ways as pre-exercise routines and have different effects on the body.

Jogging as a general warm-up routine is an aerobic activity of low to moderate intensity that usually lasts 5-10 minutes (ACSM, 2011). It is widely known that general warm-up routine can acutely improve individual's performance (Holt and Lambourne, 2008) due to the before mentioned increases in temperature and blood flow to the muscle. Being the most popular of the three routines, any study comparing the effects of warm-up routines on improving physical performance should include a jogging pre-exercise routine in the analysis.

Proprioceptive neuromuscular facilitation (PNF) is a stretching technique commonly used in rehabilitation from injuries. It is used in order to improve muscle elasticity and has been shown to have a positive effect on both passive and active range of motion (ROM) (Funk, Swank, Mikl, Fagan, and Farr, 2003). Performing PNF includes the individual's muscle being lengthened to the point of discomfort and held in that position, followed by the individual contracting the stretched muscle isometrically for a short time period. The contraction triggers relaxation of the targeted muscle through activation of the Golgi tendon organs. During this relaxation a passive stretch is applied to the contracted muscle thus allowing the muscle to be stretched beyond its previous limit (Hindle et al., 2012). Besides clinical application, many strength and conditioning coaches use the PNF technique, too. They generally use it as a warm-up routine in order to decrease injuries in their athletes (Church et al., 2001). However, there have been some contradictive reports about the effects of

PNF on force production and explosive movements (Bradley, Olsen, and Portas, 2007). Some studies found that there is no significant difference in performance following PNF stretching (Carvalho et al., 2009) and some discovered that PNF is even detrimental to performance (Church et al., 2001) presumably due to a decrease in musculotendinous stiffness which reduces the force production in the contractile component of the muscle. Some studies reported that such an adverse effect could last in the range of 15-60 minutes (Christensen and Nordstrom, 2008). The dilemma of the popularity of PNF stretching and it's potential for impairing performance requires further investigation in order to obtain definite recommendations about the effectiveness of PNF as part of a pre-exercise routine prior to physical activity and sport performance.

Whole body vibration is a term generally used when a vibration of certain frequency is transferred onto the human body as the person stands on a plate or platform capable of vibrating the body at various frequencies. The WBV treatment causes a mechanical stimulus to be transmitted within the body, which results in small rapid changes to muscle length, thus stimulating sensory receptors such as muscle spindles (Cardinale and Bosco, 2003). It is hypothesized that WBV induces neuromuscular potentiating effects by an enhanced recruitment of motor neurons and muscle fibers and therefore results in strength increase as well. These improvements are thought to occur due to the changes in the neuromuscular pattern of recruitment (Eckhardt et al., 2011). Several studies have shown that WBV can acutely benefit vertical jump and/or explosive performance (Armstrong, Grinell and Warren, 2010; Bedient et al., 2009; Cochrane and Stannard, 2005; Ronnestad and Ellefsen, 2011; Turner et al., 2011), while at least one study showed no significant difference compared to control groups (Lamont et al., 2010). Since WBV application as a performance enhancing tool is still new and relatively understudied compared to other warm-up routines its effects need further investigation and comparison to the other popular existing warm-up routines.

Vertical jump (VJ) is one of the most common sport related movements and has a direct influence on the quality of performance in many sports. Some of these sports are basketball, volleyball, football, ski jumping, and track and field. In recent years, coaches started addressing vertical jump as an indicator of an athlete's physical readiness (Ostojic, Stojanovic, and Ahmetovic 2010). They are using both single as well as multiple vertical jumps in order to assess muscular strength and anaerobic power of their athletes (Ostojic et al., 2010). It is evident that VJ is a significant part of performance in many sports and a popular means of assessment for coaches and personal trainers. In the associated literature vertical jump is most commonly measured using a counter movement jump (CMJ). Therefore the latter will be used in this study as a tool for assessing vertical jump performance.

Knowing how important VJ is and that it can be influenced the type of pre-exercise routine it was selected as the dependent variable of this investigation. Considering the conflicting reports regarding the influence of various types of pre-exercise routines on VJ this study will help confirm or reject such conflicts.

Purpose

The purpose of this study was to determine and compare the influence of three different pre-exercise routines (jogging, PNFJ, and WBV) on vertical jump performance.

Hypothesis

It was hypothesized that there would be a significant increase in vertical jump performance using both jogging and whole body vibration as a pre-exercise warm-up routine. It was also hypothesized that there would be a significant decrease following proprioceptive neuromuscular facilitation as a pre-exercise routine.

Limitations

Potential limitations of this study are having a small sample size, recruiting subjects from a single university and using a convenience sample for known males who were currently training at the university and community.

Delimitations

This study included only trained male college age students therefore the conclusions derived from this study are not applicable to females of any age or males of other ages.

Assumptions

There was an assumption that all of the participants were highly motivated, and gave their maximum effort during every jump they performed as a part of this study.

Definition of Terms

Aerobic exercise: an activity that uses large muscle groups, can be maintained continuously and is rhythmic. This type of exercise overloads the heart and lungs and causes them to work harder compared to rest (ACSM, 2013).

Counter movement jump: type of a jump where an individual starts a jump from an upright standing position, makes a preliminary downward movement by flexing the knees and hips, then immediately extends both knees and hips again to jump vertically up off the ground (Lindthorne, 2001).

Proprioceptive Neuromuscular Facilitation stretching: "promoting or hastening the neuromuscular mechanism through stimulation of the proprioceptors" (Alter, 1996). Muscle is passively stretched to its maximum length, followed by a short maximal isometric contraction against a fixed object or person. The contraction is followed by relaxation and passive stretching of the muscle (Burke et al., 2000).

Vertical jump: raising one's center of gravity higher in the vertical plane, solely with use of one's own muscles (NFL Combine).

Pre-exercise routine: a low to moderate level intensity activity, performed with aim to optimally prepare individual's body for physical exertions. This is achieved through an increase in the temperature and blood flow to the muscle, along with speeding up the cardiovascular and pulmonary system (ACSM, 2011).

Whole body vibration: a term, generally used when a vibration of certain frequency is transferred onto the human body. Vibration platforms oscillate up and down or produce reciprocal vertical displacement on the left or right side of a fulcrum, and consequently produce vibration (Armstrong et al., 2010).

CHAPTER II

REVIEW OF LITERATURE

A plethora of research has investigated the effects of various warm-up protocols and their acute influence on vertical jump performance. Despite the large number of studies on this topic, controversy exits among the findings of these studies thus providing no consensus on this topic. The conflicts between findings are likely due in part to the differences in methods, measurement techniques or different subject characteristics. For the review of the literature, this chapter is separated into the effectiveness of improving vertical jump in three factors: general pre-exercise routine (jogging), PNFJ (proprioceptive neuromuscular facilitation with jogging) pre-exercise routine, and WBV (whole body vibration) pre-exercise routine. A greater focus will be given to the research on the acute effects of WBV on VJ because it is a newer, less researched area.

General pre-exercise routine – jogging

Jogging as a general pre-exercise routine (also known as general "warm up") has been thoroughly researched. Most of the researches have shown that it does benefit exercise performance due to the previously mentioned increase in blood flow and muscle temperature (ACSM, 2011). This chapter will focus on studies that specifically researched acute effects of general pre-exercise routine on VJ performance and VJ related explosiveness.

Pagaduan, Pojskic, Uzicanin and Babajic (2012) investigated the effects of general warm-up strategy on countermovement jump (CMJ) performance, in twenty-nine male college football players (19.4 ± years old). The warm-up consisted of five minutes long running in a circle at a preset pace. There were total of 12 circles, with circumference area around 86 meters long. Pace was getting progressively higher with each four completed circles, but the intensity remained between low and moderate. The results showed that there was a significant increase in CMJ following general warm-up routine, when compared to the control group. Mean CMJ performance results for the control group were 33.7 ± 3.8 cm, while the general warm-up group jumped 38.0 ± 4.3 cm. The authors of the study stated that an increase in CMJ could be due to the improvement in muscle stiffness and nervous system activation.

Similarly, Andrade et al. (2015) compared the acute effects of a general warm-up routine on explosive performance of ten healthy subjects (20.6 ± 0.64 years). The warm-up consisted of 5 minutes long running at 70% of maximum heart rate. The results have shown that general warm-up routine induced significant increases in both squat jump (SJ), as well as in CMJ performance when compared to the control group, thus confirming the results from the Pagaudan et al. study. The authors of the study stated that the improvement in SJ and CMJ, which followed general warm-up routine can be explained by an increased muscle temperature. The increase in temperature supposedly affected muscle performance by reducing muscle's viscosity and resistance. This reduction may have induced "a smoother contraction, an increased speed of rate-limiting oxidative reaction and/or increased oxygen delivery to muscles through greater vasodilatation" (Andrade et al., 2015).

Holt and Lambourne (2008) conducted a study on the impact of 5 minutes long general, cardiovascular warm-up on VJ performance. The subjects were 63 college NCAA I football players, 18-25 years old (mean age equal to 20.7 ± 1.8 years). The results have once again shown an increase in VJ height following general warm-up, thus confirming that a general warm-up routine can acutely increase VJ performance.

Vetter (2007) conducted a research about the effects of general warm-up on VJ and sprint performance. The subjects were twenty-six college age men (n =14) and women (n =12). General warm-up routine consisted of walking and running within low to moderate intensity limits. Subjects consisted of both genders. When compared to control state, the results have shown an acute increase in CMJ following general warm-up routine. The conclusion of this study agrees with conclusions of previously mentioned studies, that a general warm-up can induce an increase in VJ performance.

In conclusion, all of the mentioned studies noted that there were significant increases in CMJ and SJ (mean increase of 4.3 ± 0.5 cm) following approximately five minutes lasting warm-up. The mechanism behind improvements in VJ, following general pre-exercise routine can be explained by an increase in muscle temperature. This affects muscle performance by reducing muscle's resistance and viscosity. The reduction in viscosity induces a smoother contraction along with an increased speed of rate-limiting oxidative reaction and/or increased oxygen delivery to muscles through greater vasodilatation. From the review of these studies, it is obvious that a general warm up, which consists of light to moderate intensity walk or run, can have a positive influence on VJ.

PNF pre-exercise routine

It is well known that many coaches administer PNF as a pre-exercise routine to their athletes. However, there is still no definitive answer whether this routine is detrimental to the performance (VJ) of those athletes. When it comes to PNF as a pre-exercise routine, the results from research studies are contradictory. Some studies have not found any significantly detrimental influence of PNF pre-exercise routine on VJ height while others have found PNF to have a negative influence on VJ performance.

Christensen and Nordstrom (2008) researched the effects of PNF on VJ performance in sixty-eight male and female NCAA I athletes. Subjects performed a 600-m jog followed by a PNF routine. The PNF stretches were led by an athletic trainer. The method involved the subject contracting the stretched muscle isometrically for 2 seconds, followed by their partner stretching it for 5 seconds. VJ was measured with Just Jump system, which consists of a 68.6 cm mobile square mat attached to a handheld computer. Validity of this system has been previously demonstrated (Church et al., 2001). It was concluded that the Just Jump system is a good alternative for testing VJ, and its reported accuracy is +/- 0.5 in. The subjects performed 3 jumps with a rest period between each jump lasting approximately 45 second in order to allow recovery and ensure maximal performance. The average of these jumps were used for statistical analysis that showed no significant difference in VJ performance in the PNF group when compared to the control group.

Carvalho, Prati, Carvalho and Dantas (2009) researched the acute effect of PNF on the VJ performance in 9 adolescent mixed tennis players (five male, four female players). The average age of the study participants was 14.4 years. Subjects initial VJ measurements were taken after a 15 minute recovery period that followed one hour of tennis practice. Each subject had three jump trials. After the initial VJ measures, subjects rested for 5 minutes prior to PNF stretching which was immediately followed by second VJ testing. After statistical analysis, the authors have not found any statistically significant changes in VJ performance, thus confirming the findings from previous study. Because VJ measurements were performed immediately after the PNF routine and were not repeated over time, the results have shown only the immediate influence of PNF on VJ performance. However it can be assumed that later measurements would not have found any decrease in VJ performance, either. The reason for this is that it is common for VJ performance to stay the same or increase with time, following the PNF routine, passing (Christensen and Nordstrom, 2008). Although this study did not use PNF technique as a pre-exercise routine, it is still a valid way of researching the effects of PNF stretching on VJ performance.

Young and Elliot (2001) studied the acute effects of the PNF pre-exercise routine on jumping performance as a part of their study. Subjects were fourteen male participants (22 ± 3 years old). The PNF routine was preceded by a 5 minutes long jog warm-up. The PNF stretches consisted of 5 seconds long isometric contraction against resistance from the tester. It was followed by relaxation and passive stretching for 15 seconds. The participant then rested for 20 seconds, before the procedure was repeated two more times. The effect of PNF stretching on performance was assessed using squat Jump (SJ) with a 10-kg bar on the shoulders.. No significant differences in VJ height between the PNF and control group were found, thus confirming the results of the previously reviewed studies in this section.

Church, Wiggins, Moode and Crist (2008) investigated the acute effects of PNF on VJ performance in 40 female NCAA Division 1 athletes (20.3 ± 1.6 years old). VJ was tested with the Just Jump system. Prior to performing PNF, the subjects completed a general warm-up routine, which consisted of a body weight circuit of 10 exercises. Exercises were getting progressively harder, and the whole routine lasted for a total of 5 minutes (20 seconds exertion, 10 second rest per exercise). The general warm-up was then followed by PNF stretching. In this study, PNF stretching involved isometrically contracting the stretched muscle for 10 seconds, followed by a passive stretch that lasted 10 seconds. There were total of three sets of stretching. Compared to the control condition there was a statistically significant decrease ($p = 0.01$; mean decrease of 1.47 ± 0.71 cm) in VJ height following the PNF pre-exercise routine. The authors of this study explained that decrease in VJ performance was partially due to the increased slack in the tendon, which results in a decrease of force production. In other words, the muscle contracts and it takes a short amount of time until the slack is taken up. The other reason for the decrease in VJ performance was attributed to the reduced reflex sensitivity of the muscle following stretching, which can result in a decreased reflex activity and force production (Avela et al., 1999). They also went as far to stating that "the longstanding belief that a more flexible muscle will produce better performances should be reexamined". This finding clearly contradicts the findings of the three previously mentioned PNF studies.

Bradley et al. (2007) researched the effects of the PNF pre-exercise routine on VJ performance in eighteen male university students (24.3 ± 3.2 years old). The PNF routine was preceded by a 5 minutes long cycling warm-up. During the PNF routine, targeted muscle was stretched to its end point, followed by subject performing a 5 seconds long maximal isometric contraction of the muscle. This was followed by a passive stretching of the targeted muscle, which lasted for 30 seconds. VJ was measured as a CMJ. The results have shown a statistically significant ($p < 0.01$) decrease in jump height by an average of 5.1% for the PNF routine in comparison with the control state. The authors of the study stated that the recorded decrease was due to the fact that "PNF stretching decreased stiffness in the musculotendinous unit, which could impair force production in muscles as a result of changes in the force velocity and length-tension relationship". This study confirms the results of the Church et al. study that PNF stretching can decrease VJ performance but disagrees with other studies that show no significant change in VJ with PNF stretching.

From these studies on PNF stretching and performance, there is no consistent effect with some studies showing no change in performance while others found PNF stretching to decrease performance. Collectively, they do show that the PNF routine does not increase VJ height. However, there are still questions whether PNF should be used as a part of a warm-up, in order to decrease the chance of injury. The differences in the findings of these studies are most likely due to the differences in time length of passive stretching and/or due to the time length of maximal isometric contraction of the stretched muscle. For comparison, in Christensen and Nordstrom study, which did not find any significant difference in VJ following PNF, maximal isometric contraction and passive stretching were performed for relatively short time (2 and 5 seconds), while in Bradley et al. (2007) study, which found that PNF decreased VJ performance, maximal isometric contraction and passive stretching lasted significantly longer (5 and 30 seconds). Similar conclusions can be made when Christensen and Nordstrom study is compared to the Church et al. study, which found that PNF routine significantly decreased VJ height. When Bradley et al. (2007) PNF procedure (5 and 30 seconds) is compared to the procedure of Young's and Elliot's study (5 and 15 seconds), which did not find any significant differences in VJ performance following the PNF routine, a significant difference can be observed in the time length of the passive stretching. Therefore it appears that the time length of passive stretching can have an influence on performance by itself. Similar statement can be made for the time length of maximal isometric contraction. When Young and Elliot PNF procedure (5 and 15 seconds) and Church et al. PNF procedure (10 and 10 seconds) are compared, it can be seen that they last the same amount of time. However there is a difference in the times of maximal isometric contraction and stretching of the targeted muscle. It appears that the increase in time length of maximal isometric contraction has a negative influence on VJ performance. This might be due to the fatiguing of the muscle, which may come with depleting of phosphagen energy source (ATP and CP) following 10 seconds of maximal effort/contraction (Mc Ardle et al., 2010).

In conclusion to this section, coaches should be aware that the PNF pre-exercise routine might decrease VJ performance in some of their athletes. Therefore they might need to measure the response of their athletes to PNF individually in order to make an informed decision, whether to use it or not. Furthermore, they might also need to experiment with the time length of the stretching, because shorter routines might have a smaller influence or no effect on VJ performance.

WBV pre-exercise routine

Whole body vibration (WBV) is a relatively new exercise modality and therefore its effects are still not fully known. Scientists have been researching WBV training effects for several years, but it has not been long since they started researching the acute effects of WBV on human performance. Despite the WBV being a new pre-exercise routine, there were several studies done on its acute influence on VJ and lower body power, which is associated with VJ outcomes (Ostojic et al., 2010). The results of these studies have mostly shown minimal improvements, in VJ performance, which were both statistically significant or non-significant. The acute effects of the WBV pre-exercise routine depend on the treatment duration along with frequency and amplitude of the vibration plate, which have yet to be fully standardized for the purpose of acutely increasing performance.

Cochrane and Stannard (2005) aimed to quantify the acute effect of WBV on arm countermovement vertical jump (ACMVJ) in eighteen female field hockey players (21.8 ± 5.9 years). Subjects were standing in various positions on the vibration plate (Galileo Sport machine) for a total of 5 minutes. The vertical amplitude of the oscillating platform was set at 6 mm, with a frequency of 26 Hz. ACMVJ was measured prior to and within the 15 seconds after stepping off the vibration plate. After that, there were additional five ACMVJs, separated by 10 seconds long resting periods. The jumps were performed according to the Harman et al. (1990) protocol and were measured to 0.1 cm. The results showed that WBV treatment produced an acute ergogenic effect, which resulted in a mean 8.1 ± 5.8% increase, when compared to the control condition. Cochrane and Stannard (2005) stated that these results are in accordance with results from previous studies by Bosco et al. (2000) and Torvinen et al. (2002). The authors have also stated that the observed enhancement in muscle power, which occurred after acute vibration, most likely happened due to the potentiation of the neuromuscular system. Consequently, the stimulation of Ia afferents (muscle spindles) resulted in reflex activation of motor neurons with increased spatial recruitment" (Komi, 2000).

Another study investigated the effectiveness of a 60 second long bout of WBV as a viable warm up activity prior to counter movement jumps (Armstrong, Grinnell and Warren, 2010). Ninety subjects (60 females and 30 males, mean age = 19 ± 1 years) were recruited for the purpose of this study. These subjects were assigned either to the control group or to groups of various vibration frequencies (30, 35, 40, 50 Hz) and amplitudes (2-4 mm or 4-6 mm). Subjects stood on a Next Generation Power Plate with the feet shoulder width apart and knees slightly flexed. CMJ was measured before and after the 60 seconds long vibration treatment. Total number of attempted CMJs was 5 times before WBV treatment and 3 times every 5 minutes for 30 minutes after WBV, with maximum jump recorded each time. Vertec vertical jump tester was used to measure CMJ performance. This jump tester has similar accuracy as Just Jump system, and is therefore reliable for use (Church et al., 2001). The results showed that an acute bout of WBV can induce a statistically significant increase in

CMJ performance ($p < 0.01$), regardless of the intensity. CMJ height peaked at 5 minutes after WBV and remained significantly increased at 10 minutes post WBV. There were no statistically significant differences in CMJ between control and immediate VJ height. The same goes for 15 minutes and longer post-WBV treatment. The authors stated that the use of WBV as a pre-exercise routine may involve a small window of improvement, which benefits VJ performance. They also concluded that there were no negative effects following a single 60 seconds long bout of WBV on CMJ. The findings of this study mostly agree with the findings of Cochrane and Stannards study. However, this study has shown a statistically significant increase in VJ height 5 minutes after the WBV protocol, while Cochrane and Stannard study found an immediate statistically significant increase in VJ performance. This could be due to the WBV duration and frequency differences between the protocols of these studies.

Study, conducted by Lamont et al. (2010) researched the acute influence of low-frequency WBV on VJ performance in twenty-one recreationally trained, college-aged males (18-30 years). Two different frequencies, 30 and 50 Hz, were applied for 30 seconds continuously or intermittently (3 x 10 second, 1 minute rest between exposures). The amplitude chosen was 4-6 mm (peak-peak). Subjects were asked to stand on the vibration platform in a quarter squat position. CMJs were performed prior to WBV. The three jumps were attempted with the highest result recorded at pre-chosen time points after the WBV treatment beginning at 2 minutes and finishing at 17 minutes post WBV. The time rest between consequent jumps was 1 minute. The findings showed no statistically significant differences in CMJ height between different experimental conditions and the control condition. However, when comparing the percent of changes there was evidence that the higher WBV frequency (50 Hz) produced significantly more post-activation potentiation (PAP) than a lower frequency, 30 Hz protocol ($p = 0.019$). PAP is a phenomenon by which muscular performance is enhanced as a result of preceding activity (Hodgson, Docherty, and Robbins, 2005), which results in better VJ performance (Lamont et al., 2010). Both continuous and intermittent 50 Hz treatments have induced a 2% improvement in CMJ after the WBV treatment. The biggest improvements were recorded around 3 minute mark post WBV. This was probably due to the fatigue predominating over PAP for the first 3 minutes (Lamont et al., 2010). The authors explained that higher Ia afferent discharge rates were elicited using the higher vibration frequency, thus inducing potentiation effects on VJ performance 3 minutes after WBV treatment. The results of this study have agreed with the two previously mentioned studies that WBV treatment may increase VJ performance. However, there were differences in the timing and intensities used between the studies. When compared to the study Cochrane and Stannard (2005), this study showed no statistically significant effects of WBV on CMJ performance, but showed a maximal increase in PAP, which is correlated to an increase in VJ performance (Lamont et al., 2010), 3 minutes post-WBV. These results are closer to the results of Armstrong et al. (2010), who reported a maximal increase in performance 5 minutes post-WBV. However, the results of the Armstrong et al. (2010) showed no significant differences between the influence of lower and higher vibration intensities on VJ performance, while this study discovered that higher intensities elicited a greater increase in PAP. This is most likely due to the differences in WBV duration between the two studies (30 vs. 60 seconds).

Turner et al. (2011) compared the effects of acute exposure to several WBV frequencies on CMJ performance. Subjects were twelve recreationally trained males (31 years ± 8). They performed a 5 minute cycle ergometer warm-up, shortly followed by measurements of their CMJ measured by Just Jump system. Participants performed two CMJs with a 3 minutes long rest between each jump. Shortly after the participants were instructed to step on vibration plate and maintain a half squat position for 30 seconds. The amplitude of the vibration plate was set to 8 mm. Four different vibration frequencies were used: 0 Hz (control), 30 Hz, 35 Hz and 40 Hz. Following the WBV treatment, participant's VJ performance was measured by 2 additional jumps. The results showed no statistically significant difference following vibration treatments with 0, 30 and 35 Hz. However, there was a significant increase ($p < 0.01$) in CMJ height following 40 Hz treatment with an average increase of 6.9%. Turner et al. (2011) concluded that WBV can result in acute improvement of VJ performance but it is dependent on the chosen frequency of vibration. This study agrees with Lamont et al. (2010), that higher vibration intensities may produce a greater effect on performance, but disagrees to the timing of the maximal changes observed. While Turner found an immediate increase in VJ performance following WBV treatment, Lamont reported an increase in PAP three minutes post-WBV treatment and no statistically significant increases in VJ height. Turner also disagrees with Armstrong et. al (2010) regarding the intensities that can elicit a significant increase in VJ performance (40 Hz vs. various frequencies), and regarding the timing of these effects (immediate vs. 5 minutes post-WBV). Compared to Cochrane and Stannard (2005), they also found significant increases in VJ performance immediately after WBV treatment. However, Turner et al. (2011) concluded that higher WBV intensities (40 Hz) are the ones that elicit a significant improvement in VJ height, thus being in direct disagreement with Cochrane and Stannard (2005), which stated that frequency of 26 Hz elicits VJ performance.

Bedient et al. (2009) attempted to identify the WBV protocol eliciting the greatest acute improvements in CMJ height which is a good indicator of leg power (Carlock et al., 2004). Forty subjects who were moderately trained males and females participated in a 5 minutes long warm-up on a cycle ergometer prior to WBV treatment. The WBV protocol consisted of participants performing isometric half squat for 30 seconds on a vibration plate. The chosen WBV frequencies were: 30, 35, 40 and 50 Hz, coupled with displacements of 2 and 5 mm. CMJs were performed before and immediately after the WBV treatment and also at 1, 5 and 10 minutes post-WBV. On each occasion, subjects were instructed to jump three times in a row with a small delay in between jumps in order to reduce the possible influence of stored elastic energy from the preceding jump. The highest jump was used in the analysis. The results showed that 30 Hz treatment produced significantly ($p < 0.026$) higher power improvements than 35 and 40 Hz treatment, but not significantly different from the 50 Hz condition.

These comparisons were accurate for both 2 and 5 mm displacements. The findings of this study differed from the results of other studies. The results from this study found that both 50 Hz (higher) and 30 Hz (lower) frequencies can elicit an increase in performance, but not the frequencies in between these two. These findings were different from Armstrong et al. (2010) study, which found that frequencies of 30, 35, 40, and 50 Hz can all produce increases in VJ performance. When it comes to timing, this study results are somewhat similar to Armstrong et al. (2010) and Lamont et al (2010). study, finding no significant increase in performance immediately after WBV, but disagreeing in the amount of time needed for this increase (1 min vs. 5 min vs. 3 min).

There were many contradicting results between the reviewed studies, especially when it comes to determining the adequate frequency and vibration time needed to elicit the biggest increase in VJ performance, and timing when this increase occurs. These studies all had different protocols: different times of the WBV treatment, amplitudes and frequencies used, some of them even had a general warm-up prior to the WBV treatment (Turner et al., 2011 and Bedient et al., 2009), while others did not. Therefore it is not possible to estimate the exact reason for their contradictions. However besides their differences, all of the discussed studies agree that the WBV treatment can elicit an increase in VJ performance. From reviewing the results of these studies it appears that 30 seconds of WBV, with frequency equal to 50 Hz and the amplitude of 4-6 mm, would be the protocol that is most likely to induce acute positive changes in VJ performance. In conclusion it should be noted that this topic needs more researching in order to be fully understood and standardized but based on the studies reviewed, it's most likely that performing WBV routine is beneficial to VJ performance.

Summary

Warm-up prior to exercise has the potential to improve performance. The studies have shown that performing 5 minutes long, light to moderate intensity jogging used as a pre-exercise routine can acutely increase VJ performance. While PNF may be a popular technique to increase flexibility and possibly reduce injury (Shellock and Prentice (1985), Ekstrand and Gillquist (1983)), it's value as a pre-exercise routine to improve vertical jump performance is in question. The results of the researches have shown that there are no significant increases in VJ performance following PNF stretching. Furthermore, the results of several of these studies have shown significant decreases in VJ height following PNF pre-exercise routines. This opens questions, whether coaches should use PNF as a pre-exercise routine for lowering the risk of injuries to their athletes and consequently risk decreasing their performance, or they should stop using PNF prior to activity.

Regarding using WBV as a pre-exercise routine, all of the reviewed studies agreed that it can elicit an increase in VJ performance. However, it should be noted that there is no standardized WBV protocol for eliciting VJ performance, but 30 seconds of WBV treatment with frequency equal to 50 Hz and amplitude of 4-6 mm appears to be the most favorable protocol to induce an increase in VJ performance. This was confirmed by Bedient et al. (2009) study, which found that WBV frequencies of 30 and 50 Hz along with duration equal to 30 seconds can elicit an increase in VJ performance. In addition, Lamont et al. (2010) found that 30 seconds long WBV treatment with frequency of 50 Hz elicits bigger PAP response in comparison with 30 Hz vibration frequency. Therefore the chosen WBV protocol of this study was 30 seconds of vibration with frequency equal to 50 Hz.

CHAPTER III

METHODS

The purpose of this study was to determine and compare the influence of three different pre-exercise routines (jogging, PNFJ, and WBV) on vertical jump performance.

Subjects

Twelve Midwestern university male students, 18 – 24 years old, who were physically active on a regular basis and were not collegiate athletes served as subjects for this study. Physically active was defined as those who participated in a minimum of three resistance exercise sessions per week for at least 6 months. Exclusion criteria consisted of recent injury with associated pain that limited exercise, specifically leg and lower back muscle or skeletal system injuries. The study was approved by the Institutional Review Board for Human Subjects and subjects gave their voluntary informed consent to participate in this study.

Subjects were instructed to refrain from lower body resistance training or heavy cardiovascular exercise for at least 48 hours prior to the testing time in order to prevent possible muscle soreness or tightness that may impair vertical jump performance. Each subject completed four different tests on four nonconsecutive days with less than three days in between any two tests. If any of the study participants reported a significant muscle tightness or soreness, he was asked to reschedule.

Protocol

This study had a cross-over design with each subject serving as his own control. On the first testing day each of the subjects performed a set of three arm-assisted CMJs without any treatment in order to assess their initial vertical jump height. These results served as the control data. The rest time between each of the three jumps was 60 seconds. The CMJs were conducted using the Vertec vertical jump tester (Sports Imports, Hilliard, OH) and vertical jump height was recorded to the nearest 0.5 inch. This procedure was in accordance with Armstrong et al. (2010) that also used a Vertec device to measure VJ performance. To begin with, each subject extended his arm up vertically as high as possible while standing on both feet with straight back and knees fully extended. At the end of the tip of the longest finger the reference height point was made on the Vertec. The reference point counted as starting height equal to 0 inches. The subjects then proceeded to perform CMJs. They were instructed to start a jump from an upright standing position, make a preliminary downward movement by flexing the knees and hips, then immediately extend both knees and hips again, in order to jump vertically. They were also instructed to swing their arms from behind the hips upwards and hit the Vertec with their fingers at the highest possible point. The height difference between the reference point of each subject and the highest point he hit during each of the jumps was recorded as the VJ for that routine.

On the first day subjects performed the initial vertical jump test. After the initial testing was done, each subject was scheduled to return at least one day later to perform one of the randomly selected pre-exercise routines; jogging, PNFJ, or WBV routine. After completing each of the pre-exercise routines the subjects performed three arm-assisted CMJs with the first jump performed within 15 seconds after the routine, a second CMJ 60 seconds after the first, and a third CMJ 60 seconds after the second CMJ. The 15 seconds post-treatment testing was chosen in order to give enough time for subjects to step to the Vertec and prepare themselves to jump and in order to measure their immediate response to the treatment. This was corresponding to Cochrane and Stannard (2005) research where the first jump was performed within 15 seconds after finishing the WBV treatment. Two 60 seconds long rests between first and second, and second and third CMJ were implemented to allow subjects recovery time between the jumps. This was done in order for their muscles to adequately replenish the phosphagen energy system and therefore minimize fatigue as a possible factor in jump performance. This matched the protocol of Bradley et al. (2007) that also had 60 seconds long rests between consecutive jumps. The best of the three jump heights was recorded for later data analysis. The jumping protocol was the same after all of the pre-exercise routines.

All of the possible orders between the pre-exercise routines were generated and the number of subjects was divided by the number of routine orders. This provided the number of participants that were assigned to a particular order of routines. There were total of six different orders of routines, which meant that each routine order was performed by two subjects each (Table 1).

Table 1. Testing Routine Order.

Number of Subjects	Routine Order
2	Jogging, PNFJ, WBV
2	Jogging, WBV, PNFJ
2	PNFJ, Jogging, WBV
2	PNFJ, WBV, Jogging
2	WBV, Jogging, PNFJ
2	WBV, PNFJ, Jogging

PNFJ – proprioceptive neuromuscular facilitation with jogging
WBV – whole body vibration

The pre-exercise jogging routine consisted of five minutes of light to moderate intensity jogging performed in accordance to ACSM's (2013) guidelines for general warm-up. Intensity was measured by the rating of perceived exertion (RPE) scale from 6-20, with 6 meaning no effort and 20 meaning maximal effort. The intensity prescribed was between 11 (fairly light) and 13 (somewhat hard). This routine was performed on a 200 meter indoor athletic track. Once the five minute jogging was completed, subjects performed the CMJ test.

The PNFJ protocol consisted of the previously described 5 minutes of jogging followed by PNF stretching. The PNF stretching technique was administered by the principle investigator. The subjects isometrically contracted stretched muscles (quadriceps and hamstrings) for 10 seconds followed by a passive stretch of these muscles for 10 seconds applied by the principle investigator. This procedure was repeated three times. The PNFJ protocol was conducted according to Church et al. (2008). The targeted muscle groups were quadriceps and hamstrings. Three CMJs were performed following the PNFJ routine in the previously described manner.

The WBV protocol consisted of subjects standing on a vibration plate (VibePlate by ProSystems, L.L.C., Lincoln, NE) in an isometrically held half-squat position for 30 seconds with vibration frequency of 50 Hz, in accordance to Bedient et al. (2009) and Lamont et al. (2010). In the reviewed literature there were various WBV protocols used but Bedient et al. (2009) and Lamont et al. (2010) had the most similar protocol settings. Therefore the WBV settings were chosen corresponding to the similar in these two studies. Three CMJs were performed following the WBV routine in the same manner as after the other two routines.

Data Analysis

Data for the initial condition, jogging, PNFJ, and WBV treatment results was entered into a spreadsheet. A three-way repeated measures analysis of variance (ANOVA) was used to determine if there were significant differences between the dependent variables ($p < 0.05$).

CHAPTER IV

RESULTS

The purpose of this study was to determine and compare the influence of three pre-exercise routines (jogging, PNFJ, and WBV) on vertical jump performance.

Upon completing the control vertical jump (VJ) test, the subjects were randomly assigned to a pre-determined routine order performed on subsequent and separate days. The means and standard deviations for the control VJ measurement and each of the routines were calculated for the twelve subjects. Results are presented in Table 2.

Table 2. Means and Standard Deviations for Vertical Jump Height Test Results.

Control	25.00 ± 4.51 in
Jogging	25.54 ± 4.46 in
PNFJ	24.75 ± 4.12 in
WBV	25.21 ± 4.45 in

PNFJ – proprioceptive neuromuscular facilitation with jogging
WBV – whole body vibration

Jogging

When compared to control ($p = 0.127$) and WBV protocol ($p = 0.207$), VJ performance was not significantly different for the jogging pre-exercise routine. However when compared to the PNFJ protocol, the jogging routine resulted in a significantly ($p < 0.018$) greater VJ performance (Table 3).

Table 3. Mean Differences and Standard Deviations of Vertical Jump Performance After Jogging Compared to Other Routines.

	Control	PNFJ	WBV
Jogging	0.54 ± 1.14 in	0.79 ± 0.99 in*	0.33 ± 0.86 in

*significantly different from jogging
PNFJ – proprioceptive neuromuscular facilitation with jogging
WBV – whole body vibration

Proprioceptive Neuromuscular Facilitation With Jogging (PNFJ)

There was no statistically significant ($p = 0.447$) difference in VJ performance after the PNFJ pre-exercise routine when compared to control. However the results showed that PNFJ pre-exercise routine resulted in significantly lower VJ performance, compared to Jogging ($p < 0.018$) and WBV ($p < 0.042$) pre-exercise routine (Table 4).

Table 4. Mean Differences and Standard Deviations of Vertical Jump Performance After PNFJ Compared to Other Routines.

	Control	Jogging	WBV
PNFJ	-0.25 ± 1.1 in	-0.79 ± 0.99 in*	-0.46 ± 0.69 in*

*significantly different from PNFJ
PNFJ – proprioceptive neuromuscular facilitation with jogging
WBV- whole body vibration

Whole Body Vibration (WBV)

There was no significant difference in VJ performance when VJ performance after WBV pre-exercise routine was compared to control ($p = 0.614$) and jogging ($p = 0.207$). However, when compared to PNFJ, WBV the VJ performance was significantly greater ($p < 0.042$) (Table 5).

Table 5. Mean Differences and Standard Deviations of Vertical Jump Performance After WBV Compared to Other Routines.

	Control	Jogging	PNFJ
WBV	0.21 ± 1.39 in	-0.33 ± 0.86 in	0.46 ± 0.69 in*

*significantly different from WBV
PNFJ – proprioceptive neuromuscular facilitation with jogging
WBV – whole body vibration

Summary

The main findings of this study were that compared to control levels, none of the chosen pre-exercise routines resulted in a statistically significant difference in VJ performance. However VJ performance was significantly greater following jogging ($p < 0.018$) and whole body vibration ($p < 0.042$) protocols compared to the PNFJ pre-exercise routine.

CHAPTER V

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine and compare the influence of three different pre-exercise routines (jogging, PNFJ, and WBV) on vertical jump (VJ) performance.

It was hypothesized that there would be a significant increase in vertical jump performance following jogging and whole body vibration pre-exercise routines and that there would be a significant decrease in vertical jump performance following PNFJ routine. While mean changes were present following each of the pre-exercise routines, no statistically significant differences were observed when compared to the control condition. This finding is consistent with some studies while inconsistent with others. However, there was a significantly greater VJ performance following jogging and WBV protocols compared to the PNFJ pre-exercise routine. This indicates that PNF has a negative impact on jump performance (Table 4). While not significantly different, there were trends of a greater VJ height following jogging and WBV pre-exercise routines compared to control (Table 3 and Table 5) so that significant differences may have been found if a greater number of subjects had been tested.

Jogging

The influence of jogging as a pre-exercise routine as found in this study is inconsistent with the findings from other studies. Pagaduan et al (2012), Andrade et al. (2015), Holt and Lamoburne (2008), and Vetter (2007) all found that performing jogging as a general warm-up routine induced statistically significant increase in VJ performance. All of the warm-up protocols had the same duration (5 minutes). However there were minor differences between the described jogging intensity. Pagaduan et al. (2012) incorporated a progressively higher pace with each of the 12 circles ran by the subjects while Andrade et al (2015) used a jogging intensity of 70% of maximum heart rate. Holt and Lambourne (2008) incorporated treadmill jogging as a general warm-up. The starting speed of 4 miles per hour was increased by 1 mile per hour with each minute for 5 minutes. Vetter (2007) incorporated walking with running as a general warm up routine but the intensity level was not stated. Differences in findings between the reviewed researches and this study might come from the different intensity used. In the present study light to moderate intensity was estimated by ratings of perceived exertion scale (11-13 on a scale 6-20) which would likely be a lower intensity than in the studies reviewed. Furthermore, the subjectivity of the scale possibly would have allowed subjects to overestimate their effort and fall below the range of prescribed intensity. The possible overestimation would have resulted in an insufficient increase in muscle temperature and blood flow, which might have been inadequate for an increase in VJ performance.

In addition it should be noted that the results of this study showed a trend for the jogging pre-exercise routine to increase VJ performance compared to the other three conditions but none of the increases were statistically significant.

Proprioceptive Neuromuscular Facilitation

The findings of this study on the effects of PNFJ pre-exercise routine are consistent with Christensen and Nordstrom (2008), Carvalho et al. (2009), and Young and Elliot (2001), all which found no significant influence of PNF on VJ performance.

On the other hand the results of this study disagreed with those of Church and colleagues (2008). Church et al. (2008) observed that there was a statistically significant decrease in VJ performance following PNF stretching. The current study incorporated the same PNF stretching protocol (10 second isometric contraction, followed by 10 second stretching; for three sets) as Church et al (2008). However there were differences in the general warm-up, which preceded the PNF stretching. The current study used 5 minute light to moderate intensity jogging, while Church and colleagues (2008) used progressively harder body weight circuit of 10 exercises as a general warm-up. Therefore the general warm-up possibly produced minor muscle fatigue or influenced their subjects in some different way than the jogging protocol in the current study. Another reason might be the fact that in the current study subjects were recreationally trained males while in Church et al. study subjects were female NCAA Division 1 athletes suggesting that perhaps the responses to PNF could be influenced by the subjects gender, level of training, or both.

The findings from this study were also inconsistent with findings of Bradley et al. (2007). The main difference was in their PNF protocol. Bradley and colleagues (2007) incorporated a routine with 5 seconds of maximal isometric contraction and 30 seconds of stretching. Therefore, the duration of stretching in Bradley's research was three times longer than the current study which used a 10 second isometric contraction and 10 second stretching. It is widely known that longer stretching duration elicits greater stretching effects (increased slack in the tendon), when compared to the stretching of shorter duration (ACSM, 2013). Therefore the differences between the findings of the two studies may likely be due to the differences in stretching duration (i.e. 30 vs. 10 seconds).

In addition it should be noted that while the results of a pre-exercise PNFJ routine did not significantly decrease VJ performance, there was a non-significant decrease in VJ performance, particularly compared to the pre-exercise jogging routine.

Whole Body Vibration

The findings of this study as to the effect of a pre-exercise WBV routine on VJ are consistent with findings of Lamont et al (2010). Both studies used the same WBV protocol and found that WBV pre-exercise routine did not significantly enhance VJ performance.

However, Cochrane and Stannard (2005) found that a pre-exercise WBV routine increased VJ performance. There were differences in both frequency and duration between that study and the current study. Cochrane and Stannard (2005) incorporated 5 minutes of WBV protocol with frequency of 26 Hz, while this study had WBV protocol that lasted 30 seconds, with a frequency equal to 50 Hz. Therefore the differences in the results possibly came from the differences in WBV duration, frequency or a combination of both. Further research is needed in order to determine the exact cause for these differences.

Armstrong et al. (2010) used a WBV protocol of various frequencies (30, 35, 40 and 50 Hz) all for 60 seconds and discovered that all of the frequencies elicited an increase in VJ performance 5 minutes post-WBV. Therefore the difference in findings between Armstrong et al. (2010) and this study could be due to the discrepancies in WBV duration or due to the fact that current study measured VJ performance less than 2.25 minutes after the WBV treatment.

Turner et al (2011) discovered that 5 minute general warm-up followed by a 30 second WBV protocol with frequency of 40 Hz produced statistically significant increase in VJ performance immediately after the WBV treatment. The difference in findings between this and Turner's study is most likely due to the lack of general warm-up in the current study. It is hard to tell what kind of influence did general warm-up have on the final result, but it is well known that general warm-up alone can increase jump performance (Holt and Lambourne, 2008). In addition there was also a difference in vibration frequency between the studies where Turner used 40 Hz, while the current study used 50 Hz.

Bedient et al (2009) found that a 5 minute warm-up, followed by 30 second WBV protocol with frequencies of 30 and 50 Hz induced an increase in VJ response. The most likely reason for different findings between this and Bedient's study is probably due to the lack of a warm-up preceeding the WBV in this study.

However, the results of this study showed a non-signficant increase in VJ performance following WBV pre-exercise routine but the increase was as great as with the pre-exercise jogging routine.

Conclusions

Based on the results of this study it is concluded that none of the three pre-exercise routines significantly improved VJ. However, jogging and WBV pre-exercise routines result in a better VJ performance compared to the PNFJ pre-exercise routine.

Recommendations

The findings of this study were obtained with a relatively small sample of Eastern Illinois University male students, with age range from 18 – 24 years. Further research would most likely benefit from a larger sample size including both genders with greater age ranges. A bigger sample size would give more statistical power. Researchers should also focus on determining the most adequate WBV intensity and duration for a possible increase in VJ performance. The most promising WBV intensity seems to be 50 Hz, with accompanying duration equal to 30 seconds. In addition the effect of jogging performed prior to the WBV routine on VJ performance should be determined in future studies.

REFERENCES

Alter, M. (1996). *The Science of flexibility* (2nd ed.). Champaign, IL: Human Kinetics.

Andrade, D., Henriquez-Olguin, C., Beltran, A., Ramirez, M., Labarca, C., Cornejo, M., ... Ramirez-Campillo, R. (2015). Effects of general, specific and combined warm-up on explosive muscular performance. *Biology of Sport, 32*(2), 123-128.

Armstrong, W., Grinnell, D., & Warren, G. (2010). The Acute Effect of Whole-Body Vibration on the Vertical Jump Height. *Journal of Strength and Conditioning Research, 24*(10), 2835-2839.

Avela, J., Kryolainen, H., & Komi, P. (1999). Altered Reflex Sensitivity After Repeated and Prolonged Passive Muscle Stretching. *Journal of Applied Physiology, 86*(4), 1283-1291.

Bedient, A., Adams, J., Edwards, D., Serravite, D., Huntsman, E., Mow, S., ... Signorile, J. (2009). Displacement and Frequency for Maximizing Power Output Resulting From A Bout of Whole-Body Vibration. *Journal of Strength and Conditioning Research, 23*(6), 1683-1687.

Bosco, C., Iacovelli, M., Tsarpela, O., Cardinale, M., Bonifazi, M., Tihanyi, J., . . . Viru, A. (2000). Hormonal responses to whole-body vibration in men. *European Journal of Applied Physiology, 81*, 449-454.

Bradley, P., Olsen, P., & Portas, M. (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.

Burke, D., Culligan, C., & Holt, L. (2000). The Theoretical Basis of Proprioceptive Neuromuscular Facilitation. *Journal of Strength and Conditioning Research, 14*(4), 496-500.

Bushman, B. (2011). *ACSM's Complete Guide to Fitness & Health: Physical Activity and Nutrition Guidelines for Every Age (1st ed.).* Champaign, IL: Human Kinetics.

Cardinale, M., & Bosco, C. (2003). The Use of Vibration as an Exercise Intervention. *Exercise and Sport Sciences Reviews, 31*(1), 3-7.

Carlock, J., Smith, S., Hartman, M., Morris, R., Ciroslan, D., Pierce, K., . . . Stone, M. (2004). The Relationship Between Vertical Jump Power Estimates and Weightlifting Ability: A Field-Test Approach. *J Strength Cond Res The Journal of Strength and Conditioning Research, 18*, 534-539.

Carvalho, F., Prati, J., Carvalho, M., & Dantas, E. (2009). Acute effects of static stretching and proprioceptive neuromuscular facilitation on the performance of vertical jump in adolescent tennis players. *Fitness & Performance Journal, 8*(4), 264-268.

Christensen, B., & Nordstrom, B. (2008). The Effects of Proprioceptive Neuromuscular Facilitation and Dynamic Stretching Techniques on Vertical Jump Performance. *Journal of Strength and Conditioning Research, 22*(6), 1826-1831.

Church, J., Wiggins, M., Moode, F., & Crist, R. (2001). Effect of Warm-Up and Flexibility Treatments on Vertical Jump Performance. *Journal of Strength and Conditioning Research, 15*(3), 332-336.

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

Eckhardt, H., Wollny, R., Müller, H., Bärtsch, P., & Friedmann-Bette, B. (2011). Enhanced Myofiber Recruitment During Exhaustive Squatting Performed as Whole-Body Vibration Exercise. *Journal of Strength and Conditioning Research, 25*(4), 1120-1125.

Ekstrand, J., & Gillquist, J. (1983). The Avoidability of Soccer Injuries. International Journal of Sports Medicine, 4, 124-128.

Funk, D., Swank, A., Mikla, B., Fagan, T., & Farr, B. (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.

Harman, E., Rosenstein, M., Frykman, P., & Rosenstein, R. (1990). The effects of arms and countermovement on vertical jumping. *Medicine & Science in Sports & Exercise, 22*, 825-833.

Hindle, K., Whitcomb, T., Briggs, W., & Hong, J. (2012). Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function. *Journal of Human Kinetics, 31*, 105-113.

Hodgson, M., Docherty, D., & Robbins, D. (2005). Post-Activation Potentiation. *Sports Medicine, 35*(7), 585-595.

Holt, B., & Lambourne, K. (2008). The Impact of Different Warm-Up Protocols on Vertical Jump Performance in Male Collegiate Athletes. *Journal of Strength and Conditioning Research, 22*(1), 226-229.

Komi, P. (2000). Stretch-shortening cycle: A powerful model to study normal and fatigued muscle. *Journal of Biomechanics, 33*, 1197-1206.

Lamont, H., Cramer, J., Bemben, D., Shehab, R., Anderson, M., & Bemben, M. (2010). The Acute Effect of Whole-Body Low-Frequency Vibration on Countermovement Vertical Jump Performance in College-Aged Men. *Journal of Strength and Conditioning Research, 24*(12), 3433-3442.

Linthorne, N. (2001). Analysis of standing vertical jumps using a force platform. *American Journal of Physics, 69*(11), 1198-1204.

Magnusson, S., Simonsen, E., Aagaard, P., & Kjaer, M. (1996). Biomechanical Responses to Repeated Stretches in Human Hamstring Muscle In Vivo. *The American Journal of Sports Medicine, 24*, 622-628.

McArdle, W., Katch, F., & Katch, V. (2010). *Exercise Physiology: Nutrition, Energy, and Human Performance* (7th ed.). Baltimore, MD: Lippincott Williams & Wilkins.

NFL Combine: Workouts & Drills. (n.d.). Retrieved July 16, 2015 from http://www.nfl.com/combine/workouts.htm

Ostojic, S., Stojanovic, M., & Ahmetovic, Z. (2010). Vertical jump as a tool in assessment of muscular power and anaerobic performance. *Medicinski Pregled, 63*(5-6), 371-375.

Pagaduan, J., Pojskic, H., Uzicanin, E., & Babajic, F. (2012). Effect of Various Warm-Up Protocols on Jump Performance in College Football Players. *Journal of Human Kinetics, 35*, 127-132.

Pescatello, L. (2013). *ACSM's Guidelines for Exercise Testing and Prescription (9th ed.)*. S.l.: Lippincott Williams & Wilkins.

Rønnestad, B., & Ellefsen, S. (2011). The Effects of Adding Different Whole-Body Vibration Frequencies to Preconditioning Exercise on Subsequent Sprint Performance. *Journal of Strength and Conditioning Research, 25*(12), 3306-3310.

Shellock, F., & Prentice, W. (1985). Warming-Up and Stretching for Improved Physical Performance and Prevention of Sports-Related Injuries. Sports Medicine, 2, 267-278.

Thompsen, A., Kackley, T., Palumbo, M., & Faigenbaum, A. (2007). Acute Effects Of Different Warm-Up Protocols With And Without A Weighted Vest On Jumping Performance In Athletic Women. *Journal of Strength and Conditioning Research, 21*(1), 52-56.

Torvinen, S., Kannus, P., Sievanen, H., Jarvinen, T., Pasanen, M., Kontulainen, S., . . . Vuori, I. (2002). Effect of a vibration exposure o on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology and Functional Imaging, 22*, 145-152.

Turner, A., Sanderson, M., & Attwood, L. (2011). The Acute Effect of Different Frequencies of Whole-Body Vibration on Countermovement Jump Performance. *Journal of Strength and Conditioning Research, 25*(6), 1592-1597.

Vetter, R. (2007). Effects Of Six Warm-Up Protocols On Sprint And Jump Performance. *Journal of Strength and Conditioning Research, 21*(3), 819-823.

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.