# THE INFLUENCE OF RECOVERY TIME FOLLOWING DIFFERENT VOLUMES OF A DYNAMIC WARM-UP ON HUMAN PERFORMANCE IN RECREATIONALLY ACTIVE MALES

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*"What could you do if you knew you could not fail?"*

- *Coach Mike Krzyzewski*

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# CHAPTER I

# INTRODUCTION

A warm up prior to any exercise or competition has been an established part of any athlete or recreational exerciser’s routine for many years. There are many different warm-up techniques, while being different; all techniques include several important factors. Duration, intensity, mode, and recovery period have all been suggested as the most important factors that are essential in maximizing the workout of exercisers and the performance of an athlete [1]. Many research studies have examined these factors and each study has offered its optimal strategy to improve performance. Traditionally, the warm up process has consisted of a short period of aerobic activity followed by some form of stretching. Static stretching has been the traditional method of choice. This involves stretching or elongating the muscle to a point of mild discomfort and holding it there for a specific time (i.e. 30 seconds) [2]. Several studies have suggested that static stretching will increase flexibility which will in turn improve performance [3] and reduce the risk of injury [4] during exercise or competition. Other studies have suggested that a warm up may be more beneficial for performance than stretching [1]. There are many effects a warm up may imitate in the body. These include: (a) decreased resistance of muscles and joints, (b) increased nerve conduction rate, (c) increased blood flow to muscles, (d) increased muscle temperature, (e) postactivation potentiation, and (f) psychological preparedness [1, 5]. While static stretching has remained part of the traditional warm up, some studies have recently found static stretching to reduce vertical jump (VJ) height [6] and sprint speed [7, 8]. Furthermore, stretching has been shown to affect musculotendinous stiffness [9] and may cause a stretched induced force deficit [10] which could negatively affect performance activities involving fore production.

Alternative methods of stretching and warming up which differ from the traditional method previously mentioned have been suggested by researchers. A dynamic warm up or dynamic stretching consists of exercises that are controlled movements throughout an entire range of motion [11]. These exercises simulate movements the muscles may encounter during exercise and competition. This type of active warm up still allows for the mechanical and psychological effects mentioned by Bishop [5] to still take place at the working muscles. Many previous studies have reported increases in VJ performance, known as an estiamte of muscle power, following dynamic warm-up routines [12-18] while others [19-21] have reported no change in VJ performance. One reason for the discrepancies between results may lie in the fact that some studies examined Division I and II athletes [15, 19, 20]. These studies found no changes in VJ performance, which could suggest that more intense warm up routine, may be needed to elicit performance gains in individuals whose training status may be greater than the recreationally trained. Nonetheless, the athletic community has reacted to the supporting evidence that dynamic stretching may be superior to traditional static stretching. In a 2009 survey by Judge et al. [22], 91% of Division I and Division III collegiate football programs in the Midwest United States reported using a combination of jogging drills and some type of sport specific drills, while 86% of the pre activity warm up lasted between

5-10 minutes in duration using some type of a dynamic warm up routine. This report suggests that athletic teams have shifted towards replacing the static stretching component during the pre workout phase of a warm-up with dynamic stretching.

Part of the growing literature involving dynamic stretching is its effect on strength and power activities. Due to the stretched induced force deficit [10], activities that require a great amount of force production (i.e. VJ) should not be performed following static stretching. Dynamic stretching has been shown to improve power output during isokinetic leg extension [23], dynamic constant external resistance (DCER) during leg extension [24], and VJ performance [13, 21, 25]. Herda et al. [10] found no changes in peak torque following dynamic stretching, but did find significant decreases in peak torque following a static stretching routine. All of these activities require a high amount of force production and could be potential predictors of athletic performance.

Other factors not involving force production include flexibility and balance. Even though flexibility is more commonly associated with static stretching, a few studies have examined the influence of dynamic warm-up routines may have on flexibility. A previous study by Faigenbaum and colleagues [6] reported increases in sit and reach flexibility following warm-up protocols utilizing static stretching and dynamic stretching exercises in children. Other studies have examined different combinations and flexibility tests to determine whether dynamic stretching may improve performance. One study by O'Sullivan et al. [26] reported decreases in flexibility following a dynamic stretching routine. Researchers have questioned whether stretching should be done before or after performance as a means of reducing injury and/or improving performance [27]. Furthermore, Ryan et al. [28] found increases in flexibility following two different volumes of a dynamic warm-up which was accompanied with significant increases in VJ height and lower body power. Due to different testing procedures, the findings regarding dynamic stretching and its affect on flexibility are inconclusive. One final study by Curry et al. [29] found no differences in flexibility between warm-up groups when isolating the hip flexor muscle using the Modified Thomas test. Balance unlike flexibility is not commonly measured even following static stretching modalities. Behm et al. [30] found static stretching to decrease balance scores on a 30 second wobble board balance test, while Costa et al. [31] also found that longer durations of static stretching may decrease overall balance in individuals.

Faigenbaum et al [6] suggests that several important variables should be considered prior to implementing a pre exercise or competition routine. Volume, intensity, and recovery time are the three main points mentioned [6]. Faigenbaum et al. [25] found differences in vertical jump and long jump performance following different loads of a dynamic warm up utilizing a weighted vest. A similar study by Thompsen et al. [18] found changes in vertical jump performance also utilizing a weighted vest in Division III athletes. Furthermore, Fletcher [16] found differences in squat jump performance due the difference in stretching velocity performed prior to the performance measure. A study by Ryan et al. [28] found decreases in muscle strength endurance following an extended volume of a dynamic warm-up, while VJ performance and power output remained constant between two volumes of a dynamic warm-up. Similar to the weighted vest studies previously mentioned, Needham et al [17] observed improvements in vertical jump performance and suggests utilizing resistance during the warm up to improve force producing performance.

Another previous study by Faigenbaum et al. [32] examined the influence of different recovery periods following dynamic warm ups, finding vertical jump performance to be superior following a dynamic warm-up for up to 18 minutes when compared to static stretching, and suggested that the affects from the dynamic warm-up are greatest between 2 and 6 minutes post warm-up, however begin to diminish after only 10 minutes post warm-up [32], while Needham et al. [17] found vertical jump performance to be best at 3 and 6 minutes post dynamic warm-up.

**Summary**

There are numerous studies examining dynamic stretching and its effects on various human performance variables. Faigenbaum et al. [6] and Bishop [1] have both mentioned that there are several important variables that must be considered when designing warm up and stretching routines to optimize subsequent performance. There is supporting evidence that increased resistance and intensity during warm up may affect high force activities; however the amount or duration of optimal intensity is still unclear. There is a brief understanding of the recovery duration needed following warm up, however at exactly what time performance is at its peak is still unknown. There is little evidence of the affect of dynamic stretching on flexibility and no known evidence of its usefulness in affecting balance.

## Statement of Purpose

The purpose of the present study was to extend upon findings in the literature, examine the acute effects of different volumes of a dynamic warm-up on human performance, and to examine the influence of recovery time following different volumes of a dynamic warm up on human performance.

## Hypotheses

1. $H_o$: Is there a difference in human performance (vertical jump, lower body power, flexibility, and balance) at different recovery periods following different volumes of a dynamic warm up?
2. $H_1$: Is there a difference in human performance (vertical jump, lower body power, flexibility, and balance) following different volumes of a dynamic warm up?
3. $H_2$: Is there a difference in human performance (vertical jump, lower body power, flexibility, and balance) at different recovery periods?

## Definitions

*Dynamic Warm up:* Exercises that are controlled movements throughout a specific range of motion which simulates actions involved during exercise and athletic events. This may be referred to as a dynamic warm up, stretching, or range of motion [12].

*Vertical Jump height:* A vertical jump is the act of raising one's center of gravity into a vertical plane by using one's muscles. It is a measurement of how high an individual may rise off the ground from a standstill or countermovement position and may be measured in centimeters [33].

*Power Output:* Power output is work produced over a given period of time. Power has been traditionally explained as Power = (Force x Distance) ÷ Time [34]. Peak Power is the greatest amount of power at any point during a specific range of motion, while average power is the average amount of power throughout a range of motion for the given period of time. Both peak and average power are typically measured in watts.

*Flexibility:* A joint's ability to move freely throughout a full and normal range of motion and is measured in degrees [35].

*Balance:* A state of body equilibrium and/or the ability to control one's weight/body. Balance was measured in contacts of a wobble board with the ground and the amount of contact time for which the total of contacts accumulated while touching the ground [30].

**Delimitations**

This study used a convenience sample of 28 subjects between the ages of 18-30 years old. Participants were required to complete a health history questionnaire and an informed consent form before any testing was performed. For participants to be eligible to participate in this study, they must have been recreationally active college students, meaning they engaged in less than 10 hours per week of physical activity and could not be competitive athletes. Furthermore, all participants in this study were not able to have any current neuromuscular diseases nor had an injury to the hip, thigh, knee, ankle, or foot within the past three months.

**Assumptions**

1. The population from which the sample was drawn is normally distributed.
2. The sample was randomly selected and the treatment order was randomly placed.
3. The data acquired meets the sphericity assumption. Requires homogeneity of variance.
4. Subjects accurately answered the health history questionnaire.
5. Equipment functioned properly for all testing sessions.
6. Participant's knowledge of any warm-up procedures and their effects on performance did not influence the outcomes during the study.

**Limitations**

1. Participants for the study were recruited from courses within the Department of Health & Human Performance, meaning there may not have been a random selection of participants.
2. Due to the amount of time needed to take specific measurements, subjects may not have experienced actual rest during the rest periods.

# CHAPTER II

# REVIEW OF LITERATURE

## *The effects of dynamic warm ups on VJ performance*

As mentioned previously, dynamic stretching has been researched extensively. Several studies have found increases in VJ following dynamic stretching [12, 13, 15, 16, 21, 25]. Faigenbaum et al. [6] compared static vs. dynamic stretching on several anaerobic performance measures in youth. This study used three treatment conditions which were a) low intensity aerobic exercise and static stretching, and b) moderate to high intensity dynamic stretching, and c) moderate to high intensity dynamic stretching with three drop jumps. The static stretch group performed a 5 minute submaximal jog prior to performing the stretching treatment. The static stretching group consisted of six exercises stretched for 15 seconds to the point of mild discomfort and repeated then switched to the other side of the body. The dynamic stretching group consisted of 10 exercises that stretch the hip adductor, hip rotators, quadriceps, hamstrings, and calf muscles. The same muscle groups were stretched by the six exercises performed during the static stretching treatment. The dynamic exercises were performed a total of 15 repetitions for each exercise covering a distance of 13 meters. A third dynamic stretching group performed a similar routine as the dynamic stretching group, however it added three drop jumps from a 15 cm box following the dynamic exercises. All three stretching groups performed the stretches and exercises for a total duration of 10 minutes. VJ, standing long jump, heart rate (HR), and a shuttle run were performed following the warm-up protocols. VJ was significantly greater for the dynamic and dynamic drop jump groups compared to the static stretching group. Long jump performance was significantly greater for the dynamic stretching group compared to the static stretching group. Again, both dynamic stretching groups saw significantly faster shuttle run times than the static stretching group. Lastly, mean HR values following the three warm-up condition were: static (109 BPM), dynamic (150 BPM), and dynamic with drop jumps (152 BPM). Both dynamic groups had significantly higher heart rate values compared to the static stretching group following the warm-up.

Faigenbaum et al. [25] examined the effects of a dynamic warm-up with and without a weighted vest on anaerobic performance measures. Eighteen healthy high school female athletes were divided into four treatment groups consisting of static stretching (SS), dynamic stretching (DY), dynamic stretching with a weighted vest of 2% of the subject's body mass (DY2), and dynamic stretching with a weighted vest of 6% of the subject's body mass (DY6). The exercises performed during both the static and dynamic stretching groups stretched the hip and lower back musculature, chest musculature, hamstrings, quadriceps, and calf, and triceps. All stretching groups performed exercises within a total of 10 minutes of stretch time. The static stretch group performed five static stretches holding each stretch for 30 seconds at the point of mild discomfort for two sets. The three dynamic stretch groups performed nine moderate to high intensity dynamic exercises. The DY and DY2 stretching groups had a significant increase in VJ compared to the static stretching group, whereas the DY6 group was only slightly higher than static stretching. The dynamic group warming up with a weighted vest of 2% of the subject's body weight also had a significant increase in long jump when compared to static stretching. The other two dynamic groups were higher than the static stretch group. There were no significant interactions among the four groups for the medicine ball toss. The findings of this study suggest that a loading of the neuromuscular response while wearing a weighted vest may have produced greater force production.

The authors suggest that post activation potentiation may be present following a dynamic warm-up. Furthermore, this study gives evidence that volume or load can become too great to improve performance. The weighted vest group with 6% body mass did perform higher than static stretching; however it was not as great as the 2% body mass group. Lastly, the authors of this study suggest that more evidence is needed in the field of warm-up design. It suggests that design, recovery period, intensity, volume, duration, and type of warm-up are all important factors that need to be considered [25].

These findings are also consistent with Thompsen et al. [18] in which the effects of a warm-up with and without weighted vests were examined. Sixteen female Division III athletes that had at least one year of resistance training experience completed three warm-up conditions: a) static stretching, b) dynamic stretching, c) dynamic stretching with a weighted vest of 10% body mass. Individuals completed five minutes of stationary cycling prior to four static stretches that stretches the calf, quadriceps, and hamstrings. Each static stretch was held for 20 seconds for three sets at the point of mild discomfort. The two dynamic stretch groups performed the same 12 dynamic stretching movements. Each subject performed the exercise for 20 yards at a moderate to high intensity. The exercises performed for the two dynamic groups stretched the calf, quadriceps, and hamstrings similarly to the static stretch group. All three warm-up groups lasted 10 minutes in duration. VJ and long jump performance were measured following the treatment conditions. VJ was significantly greater for both the dynamic stretch and dynamic stretch with vest groups when compared to the static stretch group. Long jump performance was greater for both dynamic stretching groups compared to static stretching group, Furthermore; the dynamic stretching group with a weighted vest of 10% body mass had a significantly greater long jump than the dynamic stretching only group.

This study suggests that increased volume or intensity during a dynamic warm-up may elicit greater enhancements in performance but to what extent is still undetermined. The authors also suggest that recovery period may play a key role in optimal performance following a warm-up protocol, stating that 15 seconds may be too short of a recovery period causing fatigue; however 15 minutes may remove the post activation potentiation phenomena that may facilitate possible improvements [18]. While Faigenbaum et al. [6] examined youth, other studies have examined young adults and athletes.

Hough et al. [13] assessed the effects of static and dynamic stretching on vertical jump performance and electromyography (EMG) activity of the vastus medialis. Eleven subjects performed a static and a dynamic stretch warm up that stretched the plantar flexors, hip extensors, hamstrings, hip flexors, and quadriceps muscles. The dynamic stretch group completed the exercises in 7 minutes ± 1 minute. These were done following a 5 minute submaximal cycling warm-up. This study followed previous studies in utilizing 5 slow repetitions followed by 10 quick repetitions. The static stretch group performed similar stretches however held each stretch for 30 seconds at the point of mild discomfort. These stretches were completed in a similar time period of 7 minutes ± 1 minute. A significant decrease (4.2%) in VJ performance occurred for the static stretch group while the no stretch group also saw a significant decrease (4.9%) in VJ performance. The static stretch group was significantly lower for VJ performance (9.4%) than the dynamic stretch group following the stretch treatments. Lastly, the dynamic stretch group experienced a significant increase (85%) in EMG activity of the vastus medialis muscle compared to the static stretch group. The authors suggested that the EMG readings show an increased neuromuscular response following dynamic stretching that did not occur following static stretching, and may also suggest that an increased relaxation in the muscle may occur due to static stretching, which may limit its force generating capacity while under tension [13].

With the difference between static and dynamic stretching research proving dynamic stretching to have a greater influence on VJ, studies such as Thompsen et al. [18] and Faigenbaum et al. [25] have shown differences in intensity and duration of a dynamic warm up that may optimally improve VJ performance. A study performed by Fletcher [16] investigated the effects different dynamic stretching velocities may affect jump performance. This study had 24 male participants perform three different warm-up protocols a) no stretching (NS), b) slow dynamic stretching, and c) fast dynamic stretching. A 10 minute jog was performed prior to any warm-up treatment. The two other warm-up treatments were dynamic warm-ups that incorporated exercises that stretched the muscles involved in movement of the hip, knee, and ankle joints. Each exercise was performed 10 repetitions for 2 sets. The slow dynamic warm-up (SD) was performed at a pace of 50 BPM using a metronome while the fast dynamic warm-up (FD) was performed at a pace of 100 BPM using a metronome. VJ height, drop jump height, squat jump height were all assessments taken following the warm-up protocols. VJ was significantly higher for the FD warm-up compared to the SD (4.1%) and NS (4.9%) warm-ups. Drop jump height was significantly higher following the FD warm-up compared to the SD (5.6%) and NS (9.4%) warm-ups. Also following the SD warm-up, drop jump height was significantly higher compared to NS by 3.6%, and furthermore the FD warm-up saw a 6.6% significant increase from pre to post warm-up in drop jump height. Squat jump height was significantly higher for the FD warm-up compared to the SD (1.9%) and NS (5.6%) warm-ups. Following the SD warm-up squat jump height was 3.6% significantly higher than the NS warm-up.

The authors of this study suggest that faster movements prior to performance may maintain musculotendinous stiffness, while also suggesting that contractile history may play a vital role in performance and that post activation potentiation is not temperature related. If stretch speed is increased as in the case of this study, then movements that require a faster stretch shortening cycle (SSC) may see greater increases than those warm-up movements that may occur at a slower speed [16]. While there are numerous studies that have shown increases in VJ performance following dynamic stretching, there have been several studies that have shown no improvements in VJ height.

Christensen & Nordstrom [19] investigated the effects that specific warm-up protocols may have on vertical jump performance. This study examined 68 NCAA Division I male and female athletes who performed three warm-up groups consisting of jogging only, dynamic stretching, and propioceptive neuromuscular facilitation stretching (PNF). The PNF stretching group performed four stretches using a contract-relax method. The dynamic stretching group performed eight exercises in a quick and smooth action for

5 repetitions. Both groups' exercises stretched the hamstrings, quadriceps, hip adductor, and calf muscles. There were no significant interactions found between any of the groups for VJ performance. The authors suggested that the training status of the participants may have had an influence on the results and adds to the literature that training status is an important factor in warm-up design [19].

Other studies have also used participants that may have a higher training status which may have affected the performance outcomes following a dynamic warm-up. Holt & Lambourne [15] examined 64 Division I collegiate football players and their VJ performance following four different warm-up protocols. These protocols included a no stretch, static stretch, dynamic stretch, and dynamic stretch with sport movements. All groups performed exercises that stretched the following muscles: hamstrings, gluteals, lower back, quadriceps, and hip flexors. The static stretch group performed each stretch for 5 seconds on each muscle group with a total of three sets. This was to a point of slight pain as described by the researchers. The two dynamic stretching groups performed 8 exercises with 10 repetitions on each exercise to the point of moderate intensity. The latter dynamic stretch group also included sport specific movements following the dynamic stretching exercise. VJ performance was measured for each group. All four stretch groups had significantly higher VJ heights from pre to post stretch treatment, however further analysis revealed that the static stretching group performed significantly less than the other three stretch groups. This study suggests that because the participants were highly trained individuals and were most likely familiar with a VJ test, that an individual's training status may have an effect on whether dynamic stretching will affect vertical jump performance. It appears that the more trained an individual may be, the less improvements may be seen in performance and vice versa [15].

Again, more highly trained subjects participated in a study conducted by Dalrymple et al. [20] which investigated the effects of static and dynamic stretching on vertical jump height by using 12 Division II female volleyball athletes as its participants. There were three conditions utilized in this study a) no stretching, b) static stretching, and c) dynamic stretching. All participants completed a 5 minute submaximal jog and 2 minute walk prior to performing the stretching treatment. The no stretch treatment was sitting quietly for 8 minutes. The static stretching treatment incorporated four exercises that stretched the quadriceps, hamstrings, calf, and hip extensors. The exercises were performed 3 times on each side of the body and were held for 15 seconds at the point of mild discomfort. The dynamic stretching treatment incorporated four exercises that stretched the quadriceps, hamstrings, calf, and hip extensors. Each exercise was performed for 2 sets across an 18 meter distance in a walking movement. Participants had one minute of rest prior to performing the VJ assessments. Total stretching time for all conditions was 8 minutes. There were no significant interactions among all three groups for peak VJ height. Further analysis revealed that only one participant in the static stretching group saw an increase in vertical jump height compared to 7 individuals that saw an increase in the dynamic stretching group.

The authors of this study suggested that familiarization of skill with VJ and the time period of the stretching may have had an effect on jump performance. The authors also suggest that females may have a reduced muscle stiffness which may be greater than males prior to stretching. This may cause females not to be affected as negatively as males following static stretching [20].

Unlike the previous studies that used more highly trained subjects, Jaggers et al. [21] compared ballistic (stretching in which the movement mimics a bouncing motion) and dynamic stretching routines on vertical jump performance. This study examined 20 healthy male and female college students with a mean age of 24.8 years. Five stretches were used for both the ballistic group and the dynamic group. The stretches performed targeted the muscles primarily used during a vertical jump. Those muscles were the hip flexors and extensors, hamstrings, gastrocnemius, quadriceps, and glutes. The ballistic group stretched five exercises for 30 seconds each in a bouncing motion at 126 beats per minute while completing two sets total. The dynamic stretch group completed five stretches with 15 repetitions on each exercise in a controlled manner, with 5 slow and 10 quickly. There were no significant differences between VJ height or force production between groups; however this study did find a significant difference between groups for lower body muscle power. The results of this study may be due to a mixed sample of individuals including male and female participants [21].

*The effects of dynamic warm ups on sprint performance*

Other performance measures besides VJ have been shown to improve following dynamic warm-ups. Fletcher & Jones [8] performed a study to determine the effect of static and dynamic stretching protocols on 20 meter sprint performance in rugby union players. The study looked at 97 male union rugby players who performed four different stretch groups a) passive, b) active dynamic, c) active stretch, and d) stationary dynamic.

All groups performed a light 10 minute jog prior to running two 20 meter sprints. This occurred after the stretch protocol. Each stretch protocol performed stretched the following muscle groups: gluteals, hamstrings, quadriceps, hip adductors, hip flexors, and calf muscles. The stretch groups performed each stretch for 20 seconds per muscle group holding it at mild discomfort. The active dynamic group performed the stretching exercises at a jogging pace while the stationary group performed the exercises stationary through a full range of motion. Both the passive and active stretch groups which are similar to traditional static stretching saw a significant increase in sprint time while the active dynamic group which performed its stretches at a jogging intensity saw a significant decrease in sprint time.

Fletcher and Jones suggested that the active dynamic group may have seen improvements in sprint time because the intensity and motion of the stretches mimicked that of the performance measures, sprinting. This further suggests that a potential mechanism for improvements in performance through dynamic warm-ups is the rehearsal of movement, thus increasing further proprioceptive ability. Also mentioned is the potential for an increase in core temperature which would allow for an increase in nerve sensitivity causing an increase in nerve impulse. This could potentially allow for a more rapid and forceful contraction [8].

Similar to the Fletcher & Jones [8] study, Little and Williams [36] examined pre exercise warm-up routines and the stretching within those routines on various high speed motor capacities. The study had eighteen professional English soccer players perform three treatment conditions: a) no stretch, b) static stretch, c) dynamic stretch. Subjects performed 7 minutes of jogging and various movements prior to performing stretching exercises as a general warm-up. Following the general warm-up, the static and dynamic stretch groups performed exercises that stretched the gastrocnemius, hamstrings, quadriceps, hip flexors, gluteals, and hip adductors. The static stretch group performed these exercises holding each stretch for 30 seconds at the point of mild discomfort. The total stretch time for the static stretch group was approximately 6.2 minutes. The dynamic stretch group performed movement specific exercises that stretch the same muscle groups as the static group. The total stretch time for the dynamic group was approximately 6.2 minutes. Following both stretch groups, participants then performed approximately four minutes of additional intermittent sprint and agility runs. This was followed by two minutes of rest before beginning any testing procedures. This study found no significant differences among groups for vertical jump performance. There were, however; significantly faster 10 meter sprint times for the dynamic group over the static group. Both groups experienced significantly lower 20 meter sprint times when compared to the no stretch group and the dynamic stretch group had significantly faster agility test times compared to the static and no stretch groups. This study however, incorporated more warm-up movements then previous studies, which may account for the static stretch group's performance on several measures. This study adds more to the growing literature that dynamic warm-ups can improve performance in activities that require fast movement [36].

Similar to the two previous studies examining sprint performance, Fletcher and Anness [7] examined the static and dynamic warm-up components typically incorporated in track and field. Eighteen club track and field sprinters performed three different stretching groups. Each group performed exercises that stretched the hamstrings, gastrocnemius, quadriceps, gluteals, and hip flexors. The static active stretching group performed 7 minutes of stretches to mild discomfort followed by active drills. The active dynamic group performed 7 minutes of stretches that included a 20 meter walk after each stretch and then was followed by two sets of drills that were performed in the previous group. Lastly, the static dynamic stretch group performed 7 minutes of stretches that were performed stationary with no drills following the stretching exercises. This study found no differences between female and male sprinters when performing a 50 meter sprint, but did however; find a significant decrease in 50 meter sprint time for the active dynamic warm-up group when compared to the static active group. This difference was 0.16 seconds faster for females and 0.10 second faster for males. The static dynamic group also had significantly faster 50 meter sprint times than the static active group. These were 0.11 seconds faster for males and 0.90 seconds faster for females.

This study suggests that following a dynamic warm-up protocol 50 meter sprint time may decease among elite track and field sprinters. The study also mentions that a component of sprinting is the ability to perform "explosive" activity. A potential mechanism for improving sprint performance following a dynamic warm-up is proprioceptive pre activation and movement rehearsal. This practice may allow the individual to be able to switch more rapidly from a concentric action to an eccentric action which is needed for an "explosive" activity such as sprinting [7].

Taylor et al. [37] examined similar routines with thirteen competitive Australian netball players who completed a brief submaximal run prior to either a static stretch group or dynamic stretch group. Both groups performed exercises that stretched the lower back, hamstrings, quadriceps, gluteals, hip adductors, and hip flexors. For the static stretch group, each exercise was completed two times and was held for 30 seconds to the point of mild discomfort on each side of the body each time. The total stretch time for the static group was 15 minutes. The dynamic stretch group completed exercises that gradually increased in intensity for a total time of 15 minutes. Each exercise for the dynamic group was performed throughout a full range of motion. Following the static stretch group and dynamic stretch group, a series of sport specific netball skills were performed which lasted approximately 2-3 minutes. The study examined vertical jump performance and 20 meter sprint times. This study found a significantly less vertical jump height (4.2%) in the static group when compared to the dynamic group when testing occurred prior to the sport specific skills. Also, 20 meter sprint time was significantly slower (1.4%) in the static group compared to the dynamic group when testing was performed prior to the sport specific skills. Following the sport specific skills, both static and dynamic groups had improved vertical jump performance and sprint times from pre skills to post skills (5.3% of static and 0.9% for dynamic). Furthermore, there were no significant differences between static and dynamic groups after both received the sport specific skills. The authors suggest that static stretching may acutely inhibit performance, however if followed by a sport specific skill session, then performance variables may increase. This finding shows that most sport specific skills are similar to the actions performed during a dynamic warm-up. This study suggests that future studies could look at more interactions between the two and possibly determine whether static stretching followed by dynamic or sport related skills is either detrimental to performance or may elicit improvements in performance [37].

*The effects of dynamic warm ups on flexibility and balance*

While the other performance measures such as vertical jump and power are more highly regarded, other factors may also contribute to athletic performance. Several studies have examined flexibility and balance following various static and dynamic routines. Curry et al. [29] compared three warm-up protocols and their effects on range of motion and power. Twenty four recreationally active females performed three warm-up conditions consisting of: a) 10 minutes of aerobic cycling at an RPE (rating of perceived exertion) of 10-11 on a 15 point Borg scale, b) static stretching which consisted of 6 exercises that stretched the gluteals, quadriceps, hamstrings, hip flexors, and calf, and c) dynamic stretching which consisted of 9 exercises that stretched the same muscle groups as the static stretching group. The static stretching group performed all exercises for three sets. Each exercise was held for 12 seconds to the point of mild discomfort. The dynamic stretching group performed 20 repetitions on for each exercise on each side of the body. Both warm-up protocols were 10 minutes in duration.

This study examined the performance of participants following the three warm-up protocols for the modified Thomas test (hip flexor and quadriceps flexibility), vertical jump performance, and time to peak torque. This study also looked at the recovery period following each warm-up protocol. There was no significant interaction between groups for range of motion on the modified Thomas test. There was a significant main effect for time for all three stretching groups. Range of motion was significantly greater 5 minutes post warm-up for all three condition when compared to pre test values, and was lower at 30 minutes post warm-up when compared to 5 minutes post warm-up. There were no significant changes for any condition or recovery period for time to peak torque. Time to peak torque improved 27% for the dynamic group and only 10% for the light aerobic group, while there was no change for the static group. Vertical jump performance improved only following the dynamic warm-up, but was not statistically significant. There was a main effect that was significantly less for vertical jump in the dynamic group at 30 minutes post warm-up for all three groups.

This study showed a positive change in ROM for up to 30 minutes following all three conditions, and was greatest at 5 minutes post warm-up. The authors of the study suggest that the design of the study simulated which may occur in a real athletic event, in that there would be 5 minutes post warm-up which may be the coach's last instructions to the team prior to the athletic competition. This study also makes headway into recovery period research and warm-up design along with flexibility testing using the modified Thomas test [29].

While Curry et al. [29] found differences in flexibility following dynamic and static stretching routines; Behm et al. [30] examined the effect of an acute bout of static stretching on balance. Sixteen healthy males performed two conditions a) no stretch and b) static stretch groups. Before both treatments, participants performed 5 minutes of cycling at 70 rpm with 1-kp of resistance. For the no stretch group, subjects rested for 26 minutes following the 5 minutes of cycling. The static stretching group performed four exercises that stretched the quadriceps, hamstrings, gastrocnemius, and soleus. Each stretch was held for 45 seconds in duration and was completed three times on each side of the body. A 30 second wobble board test was completed to measure contact to floor with no contact time. There was a significant interaction between the control and the static stretching groups' balance scores. The control condition demonstrated significant improvement by 17.3% in balance scores post control whereas the static stretching condition did not show any significant changes in balance. The mean balance scores for the static stretch group were however slightly lower post stretching by 2.2%. The authors suggest that static stretching may elicit a change in the peripheral nervous system which may negatively affect stability in the lower body [30]. Previously mentioned increases in performance measures following dynamic stretching have been VJ, sprint speed, and flexibility. While balance was not examined following a dynamic warm-up, static stretching did show decreases in balance.

*The effects of dynamic warm ups on power output*

Several studies have examined power output following dynamic warm-up routines. Yamaguchii & Ishii [23] examined the differences in leg extension power between static stretching and dynamic stretching. This study examined 11 recreationally active males following a within subjects design allowing each participant to perform each warm-up protocol. Both static and dynamic stretching groups performed 30 seconds worth of stretching. The static stretches were performed to the point of mild discomfort while the dynamic stretches, performing 5 slow and 10 quickly. The stretches chosen were ones that would stretch the plantar flexors, hip extensors and flexors, quadriceps, and hamstrings. The dynamic stretching group saw a significant increase from pre to post stretch treatment in leg extension power. The static stretching group saw a significant decrease from pre to post stretch treatment in leg extension power. This study found no significant differences between the dynamic and static stretch groups for leg extension power. This study suggests that a shorter stretch time still saw improvements in leg extension power following a dynamic warm-up, however even with a decrease in performance that static stretching is not significantly different than dynamic stretching following 30 seconds of stretch [23].

Again, Yamaguchi et al. [24] examined the acute effect of a dynamic stretching routine on muscular performance. Twelve recreationally active males performed two stretching groups. The dynamic stretching group performed 8 minutes of dynamic stretching allowing for the 5 slow repetitions and then 10 quick repetitions at a pace of 30 beats per minute. This was performed for 2 sets with 15 repetitions. The exercises stretched the right leg extensors and flexors. The second stretch group was simply a control group in which participants sat quietly for 8 minutes. Muscular performance was measured by dynamic constant external resistance (DCER) at 5%, 30%, and 60% of a maximum voluntary contraction. Peak power was significantly greater at all loads for the dynamic group when compared to the control group. Rate of torque development was also significantly greater for all three loads for the dynamic group compared to the control group. Finally, all three loads also had significantly greater peak velocity and a faster time to peak torque for the dynamic group compared to the control group. This study suggests post activation potentiation as a potential mechanism for the improvements in muscular performance mentioning a relationship between load and velocity. Furthermore, the authors mention that dynamic stretching may have more of an effect on the velocity of movement which in turn is important for powerful exercise movements [24].

Other studies have shown similar improvements following dynamic warm-up routines. Herda et al. [10] examined the acute effects of static versus dynamic stretching on peak torque (PT), electromyographic (EMG), and mechanomyographic (MMG) amplitude of the biceps femoris (BF) muscle during an isometric maximum voluntary contraction (MVC). Fourteen men performed both a pre test and a post test following a dynamic and static stretching routine. Peak torque was measured at 4 different joint angles for the MVC tests. The static stretching routine included 4 repetitions of 1 unassisted and 2 assisted stretches held for 30 seconds at a point of mild discomfort, while the dynamic stretching routine included 4 sets of three exercises designed to stretch the same muscles as the static stretching routine. Peak torque decreased from pre- to post-static stretching at 81° and 101°, while having no changes following the dynamic stretching. Further analysis showed EMG amplitude did not change following static stretching, but did have an increase following dynamic stretching at 81° and 101°. The authors suggested that the decreases in strength observed following static stretching may be due to mechanical rather than neural mechanisms and that dynamic stretching may affect force production differently than static stretching [10].

While the study completed by Herda et al. [10] examined isometric strength, other studies have examined peak torque following dynamic warm-up routines. Both Sekir et al. [38] and Manoel et al. [39] have examined peak torque at both 60 and 180 degrees using a dynanometer. Sekir et al. [38] explored the effects of static vs. dynamic stretching on leg extensor and flexor concentric and eccentric peak torque and electromyography (EMG) amplitude. Ten elite female track and field athletes completed three condition groups: a) no stretch, b) static stretch, and c) dynamic stretch. Both the static stretch group and dynamic stretch group completed stretches that worked the hip extensors and flexors, quadriceps, and hamstrings. The static stretch group performed two repetitions of each stretch to the point of mild discomfort and held it there for 20 seconds. The total stretch time for the static stretch group was 6 minutes ± 1 minute. The dynamic stretch group performed two sets of the same stretches as the static group however, instead of holding the stretch the dynamic group completed 15 repetitions with the first 5 slowly followed by the last 10 very quickly without a bouncing motion. The total stretch time for the dynamic group was 6 minutes ± 1 minute. Peak torque values were obtained for both the quadriceps and hamstring muscles in both concentric and eccentric motions at 60 and 180 degrees. EMG amplitude was measured on the vastus lateralis and rectus femoris at 30 and 60 degrees during a maximum voluntary contraction (MVC). This study found significant decreases in peak torque for the static stretch group for both the quadriceps and hamstrings muscle groups at both speeds (60 and 180 degrees) in both ranges of motion (concentric and eccentric). The study also found significant increases in peak torque for the dynamic stretch group for both the quadriceps and hamstring muscle groups at 180 degrees for both concentric and eccentric motions. Only significant increases were found for the dynamic group at 60 degrees in the hamstring muscles during both concentric and eccentric motions.

The authors suggested that the findings add literature of the growing area that faster movements may have greater increases following dynamic warm-ups. Furthermore, the authors suggest that well trained subjects may elicit better improvements from dynamic warm-ups as opposed to untrained subjects. This study also found a significant decrease in EMG amplitude following the static stretch protocol and a significant increase following the dynamic stretch protocol only at 60 degrees for both the vastus lateralis and rectus femoris. This finding suggests that there may be possible mechanical factors that involve viscoelastic properties of the musculotendonous unit that are involved in force production, and may be enhanced following a dynamic warm-up routine [38].

Manoel et al. [39] examined 12 healthy recreationally active females that performed three stretching conditions a) static, b) dynamic, and c) proprioceptive neuromuscular facilitation (PNF). Subjects performed 5 minutes of stationary cycling at 50 RPM prior to any of the three treatment conditions. The static stretching condition consisted only of one exercise that stretched the quadriceps. This stretch was held for 30 seconds at the point of mild discomfort and was repeated 3 times. The PNF stretch was performed in the same motion as the static stretch however it used a contract-relax movement in which the investigator placed resistance on the muscle while it was stretched. The dynamic stretching condition performed the butt-kicker exercise which stretches the quadriceps in a similar manner as the static stretch used previously. It was performed repetitively and as quickly as possible for 30 seconds and was repeated 3 times. Peak torque was measured during isokinetic knee extension at 60°sec and 180°sec. There were no significant interactions between groups for peak torque at either speed. There was however significant increases in peak torque percentages. At 60°sec, the dynamic stretch group significantly increased peak torque by 8.9% and at 180°sec the dynamic stretch group significantly increased peak torque by 6.3%. The authors of this study suggested that dynamic movements may increase power for both slow and fast movements. The authors also mention that improvements or change sin isokinetic testing may not translate to jumping, running, and athletic performance [39].

While these studies examined peak torque at 60 and 180 degreees, other literature has suggested that higher speeds may induce a greater change in performance following higher intensity warm-ups. Fletcher and Monte-Columbo [14] examined performance changes that occur following different warm-up modalities. This study had 21 healthy male collegiate soccer players perform three randomized warm-up protocols: a) no stretch, b) static passive stretch, and c) static dynamic stretch. All three stretching conditions performed a 5 minute light submaximal jog prior to receiving the stretch treatment. The static and dynamic stretching groups performed exercises that stretched the gluteals, hamstrings, quadriceps, hip adductors, hip flexors, gastrocnemius, and soleus. The static stretching group performed two sets of each exercise, holding it for 15 seconds on each side of the body at the point of mild discomfort. The dynamic stretch group performed 12 repetitions for each exercise in a controlled manner, which totaled 144 repetitions. Vertical jump height, drop jump height, peak torque at 30° sec and 300° sec, time to peak torque at 30° sec and 300° sec, EMG activity of the rectus femoris and biceps femoris, core temperature, and heart rate were all measured following the warm-up conditions. Vertical jump was significantly higher following the dynamic stretching compared to the static stretching (7.5%) and no stretching (3.9%). Drop jump height was significantly higher following both the no stretch (4.9%) and dynamic stretching (5.9%) when compared to the static stretching. Core temperature was significantly highest following the dynamic stretching compared to both the static stretching (0.18° C) and no stretching (0.19° C). Heart rate was significantly greater following the warm-up protocol for the dynamic group compared to the static and no stretch groups. The heart rate following warm-up were as follows: 92 BPM for static stretching, 130 BPM for no stretching, and 158 BPM for the dynamic stretching group. Peak torque at 30° sec was significantly greater following dynamic stretching compared to static (4.6%) and no stretching (6.2%). Peak torque at 300° sec was significantly greater following the dynamic stretching compared to static (16.5%) and no stretching (10.8%). Time to peak torque at 300° sec was significantly faster following dynamic stretching compared to static (12.8%) and no stretching (7.7%). Finally, EMG activity was significantly greater following the dynamic stretching when compared to both the static and no stretching conditions. The authors of this study suggested that the increase in heart rate and core temperature are key metabolic factors that may contribute to increases in blood flow, nerve conduction velocity, and sensitivity to nerve receptors which may all be related to the increases in performance. Greater increases in peak torque and time to peak torque were achieved at 300° sec compared to 30° sec suggesting that dynamic warm-ups may contribute more to performance measures that require faster movements [14].

Further evidence by Ryan et al. [28] found increases in VJ, power output, and flexibility following a dynamic warm-up routine. This study examined 26 recreationally active males that performed 3 conditions a) no stretch, b) dynamic warm-up, and c) dynamic warm-up with double volume. A light 5 minute submaximal jog was performed prior to all 3 treatment conditions. The no stretch condition rested quietly for 12 minutes following the light jog. Both the dynamic warm-up conditions performed 11 exercises which stretch the musculature in the lower leg which included the quadriceps, hamstrings, hip flexors, calf, hip extensors, and trunk musculature. These exercises were performed in an order in which low intensity exercises were performed first followed by moderate then high intensity exercises with a 15 second rest interval between each set. The low intensity exercises were performed with 4 repetitions completed on each leg for the low and moderate intensity exercises. The intensity exercises were performed with 6 repetitions on each leg. The first dynamic warm-up condition lasted 6 min 42 sec ± 1 min 17 sec and the double volume warm up lasted 12 min 8 sec ± 1 min 35 sec. Vertical jump height was significantly greater for both dynamic warm-up group compared to the control and both dynamic groups had significantly higher vertical jump heights from pre to post test as well. Power output was also significantly greater for both dynamic warm-up group compared to the control and both dynamic groups had significantly higher power output from pre to post test as well. Interestingly, flexibility was only significantly higher for the regular volume warm-up when compared to the control. Lastly, muscular strength endurance for the double volume dynamic warm up group saw a significant decrease of 15.6% which was approximately 4 repetitions. This was the ability to perform repetitions at 70% of a 1-RM on leg press to failure. Furthermore, the regular volume dynamic warm up did not have any significant increases in muscular strength endurance when compared to the control [28].

*The effects of dynamic warm ups on sport specific skills*

Other, more sport specific activities have also been shown to improve following a dynamic warm-up. Gergley et al. [40] investigated the effects of two different warm-ups (active dynamic and passive) on various golf skills using fifteen male competitive golfers with a USGA handicap lower than 5 points. Both stretch groups performed exercises that stretched the muscles in the trunk, shoulders, lower back, hamstrings, quadriceps, and calf. The static stretch group performed 12 exercises for three repetitions on each side of the body. Each exercise was held for 10 seconds at the point of mild discomfort. The total stretch time for the static stretch group was 20 minutes. The active dynamic stretch group performed 10 practice swings with a weighted club and was then followed by a typical golf swing warm-up routine. Participants performed three full swings in progressing order form shortest to longest club (sand wedge, 8-iron, 4-iron, fairway metal wood, and driver). Club head speed, distance, and accuracy were all recorded following each warm-up protocol. No significant differences were found, however, the active dynamic warm-up consistently performed better than the static stretch group. The authors suggested that because the participants in this study were elite in their skills of golf, the dynamic warm-up may not have had as great of an impact on the performance skills, as the skills are very difficult to obtain. Furthermore, the active dynamic warm-up was done in the same manner that most golfers use as warm-up, thus this may account for any changes that may have occurred during this study [40].

A study completed by McMillian et al. [41] looked at various lower body drills and agility drills following various warm-up routines with sixteen male and fourteen female cadets. Three warm-up treatments lasted 10 minutes in duration and consisted of exercises that stretched the trunk musculature, lower back, quadriceps, hamstrings, calf, and hip flexors. The three groups consisted of a static stretching group, dynamic stretching group, and no stretching. The static stretch group consisted of 8 stretches which were held 20-30 seconds to the point of mild discomfort for only one repetition. The dynamic stretch group consisted of 15 exercises that were performed for 10 repetitions moderately quick. This study examined the t-drill which measures agility, medicine ball toss which measures total body power, and 5-step jump test which is a measure of lower body power. All three performance measures (t-drill, 5-step jump, and medicine ball toss) significantly improved following the dynamic warm-up condition when compared to the static condition and no stretch condition. Again, these authors mentioned post activitaion potentiation (PAP) as a possible mechanism for the improvements in performance. Further mentioned in the study are increased muscle compliance due to repeated stretches that may result in less force production and neural activation [41].

Similar to McMillian et al. [41], a study conducted by Khorasani et al. [42] performed an investigation to determine the effects of static, dynamic, and static with dynamic stretching on the Illinois agility test. This study included 19 male soccer players (mean ± SD; 22.5 ± 2.5 years) that performed a within-subjects design of four different warm-up protocols that included a) no stretching, b) static stretching, c) dynamic stretching, and d) a combination of static and dynamic stretching. A four minute jog was performed prior all four treatment conditions. The no stretch group performed 2 minutes of rest. The static stretching group performed five exercises that stretched the quadriceps, hamstrings, gluteals, adductors, abductors, and gastrocnemius. These stretches were held for 30 seconds at the end of the ROM but within the pain threshold and were then repeated on the opposite side of the body. The dynamic stretching group performed the 5 exercises that stretched the gastrocnemius, quadriceps, hamstrings, adductors, and gluteals. These were performed in an alternating technique for 60 seconds at a rate of on stretch cycle every 2 seconds. The static and dynamic warm-up condition incorporated both the static and dynamic exercises in the same manner as they were completed for that group. The dynamic exercises followed the static exercises in design order. Following the warm-up conditions the participants performed the Illinois agility test which is a 10 meter by 5 meter cone test. The dynamic stretch group had significantly faster times than the static stretch (0.95 sec) and combination dynamic and static stretch (0.55 sec) groups. Also, the no stretch group had a significantly faster time than the static stretch group (0.72 sec). This study also examined the differences between more and less experienced players. Less experienced players had significantly faster times following the dynamic stretching (0.48 sec) while they also had significantly slower times following the static stretching (0.37 sec). The more experienced players had significantly faster times following the dynamic stretching (0.05 sec) while they also had significantly slower times following the static stretching (0.88 sec). The authors of this study suggest that more experienced players had a better adaptation to the dynamic warm-up than did less experienced players. This follows what other studies have mentioned that training status may have an effect on improvements in performance following various warm-ups. Furthermore, this study reveals that static stretching is detrimental to agility performance, while dynamic stretching may be useful in improving agility performance [42].

*The effects of recovery time following a dynamic warm up on performance*

As mentioned previously by Faigenbaum, et al. [6], there are other aspects of dynamic warm-ups that must be researched. Some of these aspects include volume and recovery time. Faigenbaum & McFarland [32] examined the influence of recovery time following a dynamic warm-up and static warm up on power performance in adolescent males. This study used nineteen males (mean ± SD; 16.5 ± 1.1 years) who performed two condition groups a) static stretching and b) dynamic stretching. The static stretching group consisted of exercises that stretched the gluteals, hamstrings, quadriceps, calf, hip flexors, chest muscles, and triceps. Each exercises for the static group was performed three times, holding for 20 seconds each time at the point of mild discomfort. The dynamic stretching group performed 9 different exercises that stretched the gluteals, hamstrings, quadriceps, calf, hip flexors, chest muscles, and triceps. The lower body exercises in the dynamic group were performed across 10 meters with 10 seconds rest and then performed back to the starting point. Both sets of stretching (dynamic and static) lasted for duration of 10 minutes. Vertical jump and a medicine ball toss were measured pre and post treatment condition. During post treatment condition, both VJ and medicine ball toss were measured every two minutes up to 22 minutes. Vertical jump was significantly greater following the dynamic warm-up as compared to the static warm-up at 2, 6, 10, 14, and 18 minutes. Vertical jump was significantly higher at two (2.6%) and six (3.9%) minutes post warm-up compared to baseline following the dynamic warm-up. Also, vertical jump was significantly lower at 14, 18, and 22 minutes when compared with 2 and 6 minutes following the dynamic warm-up. There were no significant interactions between groups for the medicine ball toss. There was however a significant main effect for time following the dynamic warm-up at two (2.5% greater) and six (3.0% greater) minutes when compared to baseline. The authors suggest that vertical jump performance may be superior following a dynamic warm-up for up to 18 minutes when compared to static stretching. Furthermore, the authors suggest that the affects from the dynamic warm-up are greatest between 2 and 6 minutes post warm-up, however begin to diminish after only 10 minutes post warm-up [32].

While Faigenbaum examined recovery period following a dynamic warm-up on VJ performance, a similar study examined recovery time and its effects on golf swing performance. Moran et al. [43] examined eighteen experienced male golfers (mean ± SD;

23.2 ± 2.3 years) who performed three treatment groups that consisted of a dynamic group, static group, and control group. All stretches worked the muscles located in the trunk, shoulders, and lower body. The dynamic stretching group performed 8 exercises for 3 sets with 10 repetitions per each set. Each exercise was performed slowly through a full range of motion and was followed by 20 seconds of rest. The same numbers of stretches were used for the static group and were simply held at the point of mild discomfort for 30 seconds followed by 20 seconds of rest. Post test measurements consisted of club head speed and ball speed measured at four different time periods (immediate, 5 minutes, 15 minutes, and 30 minutes) following the warm-up protocol. Club head speed and ball speed were both significantly greater for the dynamic stretch group compared to both the control and static stretch group. There were no significant differences between any time periods following the stretch treatment for any stretch group. Again the authors of this study suggest that the dynamic warm-up incorporated more rehearsal of the movements that would be performed during the post testing, thus the reason for the increases in club head speed and ball speed. This is just one of only a few studies which have examined several sport specific movements and effects for dynamic stretching as well as examining the rest periods following warm-up [43].

Lastly, Needham et al. [17] examined the acute effects of different warm-up protocols on anaerobic performance. This study had 20 elite youth soccer players perform three treatment groups which were static stretching, dynamic stretching, and dynamic stretching with resistance. All groups performed a 5 minute light jog prior to the stretching treatments. The stretches used for the static stretching group and both the dynamic stretching groups were describes previously by Thomspen et al. [18]. The dynamic stretching group with resistance performed 8 front squats with 20% of the subject's body mass, immediately following the dynamic stretching routine. Vertical jump height, 10 meter sprint time, and 20 meter sprint time were all measured immediately following warm-up, 3 minutes following, and 6 minutes following the warm-up. The dynamic stretching with resistance had significantly greater vertical jump performance than both the static and dynamic stretching groups. Furthermore, the dynamic stretching with resistance also had significant improvements in sprint times at 10 and 20 meter sprints compared to the static and dynamic stretching groups. The dynamic stretching group did also see significant improvements in vertical jump and sprint performance compared to the static stretching group. The dynamic stretching with resistance group also saw significant improvements in vertical jump at both 3 and 6 minutes post warm-up compared to static and dynamics stretching groups, however not for sprint performance. The dynamic stretching group had significantly improved sprint performance over the static stretching group for 20 meter sprint time up to 6 minutes post warm-up. The authors of this study suggest that additional load on the body may take advantage of the stretch shortening cycle (SSC) in fast twitch muscle fibers and may enhance movement activities; however this may not translate to horizontal forces such as sprinting. Jumping performance was best at 3 and 6 minutes post warm-up which the authors suggest PAP and fatigue may share a relationship. The authors comment on achieving optimal PAP as being a catch 22 in that high intensity activity may elicit the greatest amounts of PAP; however those activities also bring the onset of the most fatigue as well [17].

# CHAPTER III

# METHODOLOGY

## Participants

A convenience sample of 28 healthy recreationally active males [(mean ± SD) age, 21.3 ± 1.4 years; height, 178.0 ± 6.3 cm; weight, 80.9 ± 10.7 kg] were recruited for this investigation. Of the 28 participants, 15 reported engaging in 2-4 $h \cdot wk^{-1}$ of aerobic exercise, 17 reported engaging in 2-8 $h \cdot wk^{-1}$ of resistance training exercise, and 19 reported engaging in 2-8 $h \cdot wk^{-1}$ of recreational sports. All participants filled out a written informed consent document and a Pre-Exercise Testing Health & Exercise Status Questionnaire following the approval from the Oklahoma State University Institutional Review Boards for Human Subjects. Participants were not permitted to participate if they had any current or ongoing neuromuscular diseases or musculoskeletal injuries specific to the ankle, knee, or hip joints within the last three months.

## Research Design

A counterbalanced, repeated measures design (CON x WU1 x WU2) was used to examine the acute effects of recovery time on different volumes of a dynamic warm-up routine on vertical jump height, lower body power output, hamstring flexibility, hip flexor flexibility, and lower body balance. Participants visited the laboratory four times separated by 2-5 days based on the participant's schedule. All sessions were performed at the same time of day (± 2 hrs) for each participant. The first testing session served as a familiarization session. Subjects were randomly assigned to groups using a random number table. Following the familiarization session each subject performed three randomly ordered conditions: a) control (CON), b) a dynamic warm-up routine (WU1), and c) a dynamic warm-up routine with twice the volume of WU1 (WU2). The WU1 condition was performed for 3 minutes ± 13 seconds and the WU2 condition was performed for 5 min 51 sec ± 31 seconds. During each testing session, the participants underwent a pre-condition assessment, a five minute jog on a treadmill between 6.4 – 9.7 $km \cdot h^{-1}$, the warm up condition, and the post-condition assessments that were measured at three different time periods: a) 0 minutes, b) 10 minutes, and c) 20 minutes following the condition. The treadmill speed included a range to accommodate individual differences in running ability which is a minor limitation to the study. The same treadmill speed for each participant was consistent for each testing session. The following tests were performed by all participants during each assessment trial in the following order: a) Thomas test measuring hip flexor flexibility, b) Straight Leg Raise Test (SLR) measuring hamstring flexibility, c) a vertical jump and power assessment, and d) a wobble board test for balance. For the CON condition, the participants completed the pre-condition assessments, a five minute jog, then sat and rested for 5 minutes, followed by the post-condition assessments measured at 0 minutes, 10 minutes, and 20 minutes following the condition.

## Variables

The independent variables included:

a) Time (pre vs. 0 min post vs. 10 min post vs. 20 min post)

b) Condition (CON vs.WU1 vs. WU2)

The dependent variables that were measured included:

a) Vertical Jump height (VJ)

b) Lower Body Power Output

    a. Peak Power

    b. Average Power

c) Hamstring Flexibility

d) Hip Flexor Flexibility

e) Balance

    a. number of contacts (lost balance)

    b. total time balanced

## Familiarization Session

Two to five days prior to the experimental sessions, each participant signed the informed consent form, completed the health status questionnaire, determined the appropriate five minute treadmill jog speed, practiced the performance assessments (flexibility, balance, and vertical jump), and dynamic stretching exercises to ensure that they were comfortable with the procedures and to minimize any potential learning effects.

## Flexibility

Participants completed the Thomas test and Straight Leg Raise Test (SLR). A Pro 360 Digital Protractor (SmartTool Technology Inc., Oklahoma City, OK) was used to measure flexibility for both tests. The protractor was reset to a zero angle before each measure. The Thomas test measures hip flexor flexibility. Appendix C provides a visual representation of the flexibility assessment. Participants were positioned supine on a table so that the gluteal fold was located at the end of the table and both knees were held to the chest. The participant was instructed to lower his right leg until it was at rest in a relaxed manner. The digital protractor was placed on the anterior aspect of the thigh midway between the inguinal fold and patella upon the recommendation of Ferber et al. [44]. The second flexibility test performed was the Straight Leg Raise Test (SLR) which measured hamstring flexibility. Appendix D provides a visual representation of the flexibility assessment. The subjects were positioned supine on a table. The investigator passively raised the right leg into hip flexion while keeping the knee fully extended until significant resistance was detected by the investigator, or the subject reported mild discomfort. The digital protractor was placed on the anterior aspect of the lower leg just above the medial and lateral malleolus upon the recommendation of Walsh et al. [45]. Both tests occurred on the right leg of the individual and only one measurement was taken during each pre treatment assessment and during all three post treatment test periods.

## Vertical Jump

Participants completed one maximal countermovement vertical jump (VJ) trial on a Just Jump™ mat (Probotics, Inc., Huntsville, AL) prior to each condition and during the three post condition assessments. The Just Jump™ mat calculates VJ height (cm) based on time in the air, which is the time period between the participant's feet leaving contact with the mat until the participant's feet became back in contact with the mat. Appendix E provides a visual representation of the VJ assessment. The Just Jump mat has been found statistically valid by Leard et al. [46]. To complete the VJ trials, participants were instructed to stand on the mat; with their feet shoulder width apart and their hands placed on their hips to avoid different jumping techniques. A quick downward squat movement was allowed prior to the ascending vertical jump, with no steps allowed. Participants were also instructed to land in the same position prior to the vertical jump. The jumping protocol was similar to that of previous studies [28, 47].

**Power Output**

To determine lower body power output, a Tendo Weightlifting Analyzer (Tendo Sports Machines, Slovak Republic) was used according to the protocol of Rhea et al. [47]. Each participant's body mass was entered into the Tendo unit. To properly test for power during the VJ trial, the cord was attached to a belt placed at the waistline of each participant. This allowed for proper jumping technique, while the Tendo unit was positioned just behind the subject on the floor during the test in accordance with Tendo User's Guide and the recommendation of Jennings et al. [48]. The Tendo unit then calculated both a peak power and average power output value during each VJ assessment. Appendix E provides a visual representation of the power assessment.

## Balance

Lower body balance was measured in several different ways. A Wobble Board Kinematic Measurement System (Fitness Technology Inc., Australia) was used to measure the number of balance contacts with the ground (loss of balance) and the amount of time balanced. Ground contacts were measured when the wobble board touched the floor apparatus while balance time was measured by the amount of time the contact lasted for while on the ground. The participants stood on the wobble board with their feet slightly apart. Standing erect, subjects performed a 30 second balance test in which the participant attempted to keep the board from touching the ground. The balance test was performed once during the pre-test measurements and then once during each of the three post testing periods. The balance protocol performed was similar to that of Behm et al. [30]. Appendix F provides a visual representation of the balance assessment.

## Dynamic Warm-up Exercises

The dynamic warm-up exercises were performed from low to high intensity with a 15-second rest period between each set of exercises. For the WU1 condition, two repetitions were completed on each leg for the three low intensity exercises [Appendix B (A-C)] and five moderate intensity exercises [Appendix B (D-H)], while three repetitions were completed on each leg for the high intensity exercises [Appendix B (I-K)]. For the WU2 condition, the same eleven exercises were completed using the same methods for the WU1 condition; however each subject completed double the amount of repetitions.

The three low intensity exercises were a) walking knee lift, performed by stepping forward with left leg and flexing right hip and knee to move the right thigh to chest, grasp the front of the upper shin and use arms to pull the right knee up further and squeeze against chest, keep torso erect, pause for a moment, then proceed to step down by shifting body weight to the right leg, and repeat the motion on the left leg, b) walking butt kick, performed by stepping forward with left leg and flexing right knee to move the right heel to buttocks, grasp the front of the lower shin and use right arm to pull the right heel further and squeeze against butt, keep torso erect, pause for a moment, then proceed to step down by shifting body weight to the right leg, and repeat the motion on the left leg, c) walking leg cradle, while walking, the leg is crossed in front of body, while gently lifting the foot towards the abdomen which brings the leg to a parallel position with the ground, keep the torso erect, pause for a moment, then proceed to step down by shifting body weight to the opposite leg, and repeat the motion on other side.

The five moderate intensity exercises were d) dog and bush, performed by abducting the left knee to waist height, slowly adduct the knee to midline of the body, then lowered to the ground, repeat with other leg e) straight leg march, performed with both arms extended in front of body shoulder high, perform hip flexion with knee fully extended of the right leg in front of your body touching your hands in front, keep torso erect, swing back to slightly ahead of starting position, and repeat on other leg f) forward lunge with opposite arm reach, performed by taking an exaggerated step forward with right leg, allow the right hip and knee to flex keeping the right knee directly over the right foot while maintaining the thigh parallel to the ground, reach up high with the left arm, keep torso erect, pause for a moment, bring left leg forward to standing position, repeat on left leg g) forward lunge with elbow instep, performed by taking an exaggerated step forward with right leg, allow the right hip and knee to flex keeping the right knee directly over the right foot while maintaining the thigh parallel to the ground, lean forward bringing the right arm forward and touching the right elbow to the instep of the right foot, bring left leg forward to standing position, repeat on left leg, h) lateral lunge, performed by taking an exaggerated step laterally with right leg, allow the right hip and knee to flex keeping the right knee directly over the right foot while extending the left trail leg, keep torso erect, bring trail left leg to right leg in standing position, face the opposite direction, repeat on left leg.

The three high intensity exercises were i) high knee run, performed in a rapid motion by stepping forward with left leg and flexing right hip and knee to move the right thigh to chest, keep torso erect, then proceed to step down by shifting body weight to the right leg, and repeat the motion on the left leg, j) running butt kicks, performed in a rapid motion by stepping forward with left leg and flexing right knee to move the right heel to butt, keep torso erect, then proceed to step down by shifting body weight to the right leg, and repeat the motion on the left leg, k) high knee skips, performed by stepping forward with left leg and flexing right hip and knee to move the right thigh vertically, keep torso erect, then proceed to step down by shifting body weight to the right leg, and repeat the motion on the left leg. While skipping, emphasis should be placed on height, a high knee lift, arm action, and power.

All of the dynamic warm-up exercises have been discussed in detail previously in research [18, 34, 37, 49].

**Statistical Analysis**

A 3 x 4 repeated measures ANOVA (time x condition) was used to analyze each of the following dependent variables: VJ height, peak power output, average power output, hip flexor flexibility, hamstring flexibility, and balance [number of ground contacts and total time balanced]. When appropriate, post hoc analyses included one-way repeated measures ANOVA with bonferroni corrected paired-samples *t*-tests. SPSS software (version 17.0, Chicago, IL) was used for all statistical comparisons. An alpha level was set at $P \leq 0.05$ to determine any statistical significance.

CHAPTER IV

RESULTS

*Preliminary Analysis*

**Descriptive Statistics**

The following results describe the sample of this study [(mean ± SD) age, 21.3 ± 1.4 years; height, 178.0 ± 6.3 cm; weight, 80.9 ± 10.7 kg, aerobic exercise 1.6 ± 0.2 hours, resistance training 2.6 ± 0.5 hours, recreational activity 2.7 ± 0.5 hours].

**Assumptions**

- *Randomization*: A random number table was used to counterbalance the study.
- *Normality*: This assumption was met by having an n > 12, as well as, an equal n in each condition.
- *Covariance:* Mauchly's Test of Sphericity was used to test for covariance for each variable. If the the p value failed to reject the null, than spherícty was assumed. If the p value rejected the null, than the Greenhouse-Geisser correction was used to meet sphericity. The following are the results of Mauchly's Test: Thomas Test: p = .204, SLR Test: p = .067, Vertical Jump: p = .021, Peak Power: p = .258, Average Power: p = .003, Balance Contacts: p = .048, Balance Time: p = .748
- *Equal variance*: An Fmax test was used to test for homogeneity of variance for each variable. The Fmax test was tested at 12, 27 df with a value less than 4.59

would reject the null hypothesis, meaning equal variance was met. The following are the results of the Fmax tests: Thomas test: 1.28, SLR test: 1.16, Vertical Jump: 1.10, Peak power: 1.19, Average power: 1.21, Balance Contacts: 1.73, Balance Time: 1.50 all rejecting the null hypothesis, showing equal variance.

*Hamstring Flexibility*

Table 1 includes the pre and post warm up mean (SEM) values for the straight leg raise test which measured hamstring flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a significant two way interaction (time x condition, $p = .004$). The effect size for the interaction was $\omega^2 = .129$ (trivial based upon the recommendation of Rhea [50]). Hamstring flexibility significantly increased for both the WU1 and WU2 conditions from pre to 0 min post warm up (WU1: $p < .001$; WU2: $p < .001$) while also significantly decreasing from 0 min post to both 10 min (WU1: $p = .005$; WU2: $p = .003$) and 20 min (WU1: $p = .033$; WU2: $p < .001$) post condition. Hamstring flexibility also significantly increased from pre to 10 min post warm up ($p = .006$) for the WU2 condition. Follow-up analysis resulted in a significant difference among conditions immediately post warm up ($p = .012$). The WU1 condition had significantly greater hamstring flexibility than the CON condition ($p = .015$) while there was no significant difference between CON and the WU2 conditions ($p = .083$). Refer to Figures 1, 2, and 3 for a descriptive representation of the results.

TABLE 1. Pre and post warm up mean (SE) values for hamstring flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Hamstring Flexibility (degrees) | | | | |
|---|---|---|---|---|
| Condition | Pre | 0 min Post | 10 min Post | 20 min Post |
| CON | 88.6 (3.57) | 90.3 (3.86) | 89.1 (3.53) | 88.7 (3.61) |
| WU1 | 88.5 (3.46) | 93.7 (3.72)*† | 90.8 (3.80)‡ | 89.3 (3.74)‡ |
| WU2 | 86.7 (3.55) | 93.2 (3.89)* | 90.5 (3.99)*‡ | 89.0 (3.86)‡ |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

† indicates a significant ($P \leq 0.05$) difference from CON condition

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

*Hip Flexor Flexibility*

Table 2 includes the pre and post warm up mean (SEM) values for the Thomas test which measured hip flexor flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a non significant two way interaction (time x condition, $p = .099$). Follow-up analysis resulted in a significant main effect for time ($p = .003$) with no significant main effect for condition ($p = .862$).The effect size for time was $\omega^2 = .158$ (trivial). There was a significant decrease in flexibility from 0 min post to 10 min ($p = .015$) and 20 min ($p = .010$) post for the WU2 condition. Refer to Figures 4 and 5 for a descriptive representation of the results.

TABLE 2. Pre and post warm up mean (SE) values for hip flexor flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Thomas Test (degrees) | | | | |
|---|---|---|---|---|
| Condition | Pre | 0 min Post | 10 min Post | 20 min Post |
| CON | 16.3 (1.46) | 16.6 (1.32) | 15.7 (1.32) | 16.3 (1.40) |
| WU1 | 15.6 (1.36) | 17.3 (1.32) | 16.0 (1.13) | 16.3 (1.23) |
| WU2 | 16.7 (1.44) | 17.3 (1.38) | 15.1 (1.30)‡ | 14.7 (1.38)*‡ |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

*Vertical Jump*

Table 3 includes the pre and post warm up mean (SEM) values for vertical jump height of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a significant two way interaction (condition x time, $p = .013$).The effect size of the interaction was $\omega^2 = .111$ (trivial). Follow-up analysis resulted in a significant difference in VJ height ($p < .001$) immediate post test among conditions. VJ height was significantly higher for both the WU1 and WU2 conditions (WU1: $p = .001$; WU2: $p = .006$) conditions compared to the CON condition at 0 min post warm up. VJ height significantly increased from pre to 0 min post ($p = .003$) for the CON condition, while also significantly decreasing from 0 min post to 20 min post CON condition ($p = .001$). VJ height significantly increased from pre to 0 min post for both WU1 and WU2 conditions (WU1: $p < .001$; WU2: $p < .001$). Furthermore, VJ height significantly decreased from 0 min post condition to both 10 min (WU1: $p < .001$; WU2: $p < .001$) and 20 min (WU1: $p < .001$; WU2: $p < .011$) for both WU1 and WU2 conditions. Further analysis also resulted in VJ height remaining significantly higher at 10 min post WU1 condition when compared to pre test values ($p = .011$). Refer to Figures 6, 7, and 8 for a descriptive representation of the results.

TABLE 3. Pre and post warm up mean (SE) values for the vertical jump test of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | | **Vertical Jump (inches)** | | |
|---|---|---|---|---|
| Condition | Pre | 0 min Post | 10 min Post | 20 min Post |
| CON | 19.6 (0.60) | 20.3 (0.60)* | 20.1 (0.64) | 19.7 (0.62)* |
| WU1 | 19.8 (0.62) | 21.2 (0.64)*† | 20.4 (0.60)*‡ | 19.9 (0.59)‡ |
| WU2 | 19.6 (0.59) | 21.1 (0.59)*† | 20.2 (0.60)‡ | 19.8 (0.60)‡ |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment
† indicates a significant ($P \leq 0.05$) difference from CON condition
‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

*Peak Power*

Table 4 includes the pre and post warm up mean (SEM) values for peak power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a non significant two way interaction (condition x time, $p = .078$). Follow-up analysis resulted in a significant main effect for time ($p < .001$) with no main effect for condition ($p = .778$). The effect size for time was $\omega^2 = .225$ (trivial). There was a significant decrease in peak power from 0 min post to 20 min post CON condition ($p = .002$) with a significant decrease in peak power from 10 min post to 20 min post CON condition ($p = .034$). Peak power significantly increased for both WU1 and WU2 from pre to 0 min post condition (WU1: $p = .021$; WU2: $p = .003$). Refer to Figures 9 and 10 for a descriptive representation of the results.

TABLE 4. Pre and post warm up mean (SE) values for peak power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | | **Peak Power (watts)** | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 2142.2 (75.31) | 2152.6 (74.84) | 2130.0 (73.12) | 2064.2 (68.05)‡ |
| WU1 | 2087.5 (76.37) | 2187.4 (77.80)* | 2147.8 (81.02) | 2108.7 (75.27) |
| WU2 | 2117.9 (75.52) | 2183.0 (75.63)* | 2121.9 (73.85) | 2101.0 (71.45) |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

*Average Power*

Table 5 includes the pre and post warm up mean (SEM) values for average power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a non significant two way interaction (condition x time, $p = .119$). Follow-up analysis resulted in a significant main effect for time ($p < .001$) with no main effect for condition ($p = .167$). The effect size for time was $\omega^2 = .370$ (minimal).

Further analysis resulted in a significant increase in average power for both WU1 and WU2 from pre to 0 min post condition (WU1: $p < .001$; WU2: $p < .001$). Average power significantly decreased from 0 min to 20 min post WU1 condition ($p = .023$), while also significantly decreasing from 0 min to both 10 min ($p < .001$) and 20 min ($p < .001$) post WU2 condition. Refer to Figures 11 and 12 for a descriptive representation of the results.

TABLE 5. Pre and post warm up mean (SE) values for average power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | **Average Power (watts)** | | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 1143.3 (39.52) | 1171.1 (43.48) | 1140.9 (39.80) | 1141.6 (42.80) |
| WU1 | 1142.5 (43.81) | 1205.2 (46.94)* | 1185.4 (39.97) | 1149.0 (44.26)‡ |
| WU2 | 1134.3 (40.63) | 1208.2 (42.62)* | 1148.2 (42.37)‡ | 1152.2 (38.68)‡ |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment
‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

*Balance Contacts*

Table 6 includes the pre and post warm up mean (SEM) values for balance contacts of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a non significant two way interaction (condition x time, $p = .571$). Follow-up analysis resulted in a significant main effect for time ($p < .001$) with no main effect for condition ($p = .296$).The effect size for time was $\omega^2 = .305$ (trivial). Contacts significantly decreased from pre to 0 min ($p = .031$), 10 min ($p = .022$), and 20 min ($p = .002$) post CON condition. Lastly, contacts significantly decreased from pre to 10 min post WU2 condition ($p = .026$). Refer to Figures 13 and 14 for a descriptive representation of the results.

TABLE 6. Pre and post warm up mean (SE) values for balance contacts of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | | Balance Contacts | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 27.2 (1.46) | 25.9 (1.44) | 25.4 (1.29) | 22.6 (1.02)*‡ |
| WU1 | 25.3 (1.25) | 24.4 (1.25) | 22.8 (1.21) | 22.3 (1.59) |
| WU2 | 26.4 (1.59) | 26.7 (1.78) | 23.4 (1.34)* | 23.3 (1.30) |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

*Balance Time*

Table 7 includes the pre and post warm up mean (SEM) values for balance time of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions. A 3 x 4 repeated measures ANOVA resulted in a non significant two way interaction (condition x time, p = .602). Follow-up analysis resulted in a significant main effect for time (p < .001) and a significant main effect for condition (p = .039). The effect size for time was $\omega^2$ = .256 (trivial) and condition was $\omega^2$ = .114 (trivial). There was a significant difference between the control and WU1 condition (p = .039), with a significant difference occurring at 20 min post condition (p = .022). Balance time significantly increased from pre to both 0 min (p = .045) and 20 min (p = .002) post WU1 condition, and a significant increase in balance time from pre to 10 min post WU2 condition (p = .009). Refer to Figures 15 and 16 for a descriptive representation of the results.

TABLE 7. Pre and post warm up mean (SE) values for balance time of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | | Balance Time (seconds) | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 16.9 (0.57) | 18.1 (0.59) | 18.2 (0.57) | 18.2 (0.45) |
| WU1 | 17.9 (0.53) | 19.1 (0.55)* | 19.1 (0.53) | 19.6 (0.59)* |
| WU2 | 17.6 (0.66) | 18.0 (0.64) | 18.8 (0.59)* | 18.4 (0.60) |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

# CHAPTER V

# DISCUSSION

The results of the current study extend upon previous findings in which dynamic warm up routines have improved vertical jump [12, 13, 25, 51], muscle power [23], and flexibility [6, 28, 29]. Faigenbaum et al. [6] mentioned that duration and recovery time are important variables that should be manipulated to develop the appropriate warm up design for optimum performance. The results suggest that approximately 3 minutes and 6 minutes of a dynamic warm-up following a five minute light aerobic jog may increase VJ height, lower body power, and hamstring flexibility, while having a minimal effect on balance and no effect on hip flexor flexibility. Furthermore, the results suggest that improvements in VJ, lower body power, and hamstring flexibility are greatest at 0 minutes post warm up compared to 10 minutes and 20 minutes post warm up.

## Vertical Jump

The results of the current study extend upon previous findings [25, 28, 51] in which VJ increased following a dynamic warm up. The present study found that acute increases in VJ height were highest immediately following both 3 minutes (7.1%) and 6 minutes (7.7%) of a dynamic warm-up. This improvement is however short lived, as VJ height significantly decreased following both volumes of the dynamic warm up from 0 minutes to 10 minutes post warm up (WU1: 3.0% and WU2: 3.1%) and then again from 10 minutes to 20 minutes post warm-up (WU1: 0.5% and WU2: 1.0%). While Faigenbaum et al. [32] found VJ height to be greatest at 6 minutes post dynamic warm up and significantly greater from baseline at 2 minutes post warm up, the findings of the present study had the highest VJ values immediately post warm up. There was no test period between 0 minutes and 10 minutes post warm up which may account for the disparity between studies. The present study found decreases in VJ at 10 minutes and 20 minutes post dynamic warm up which were comparable to decreases found by Faigenbaum et al. [32] in which VJ was significantly lower at 14, 18, and 22 minutes post warm up. Furthermore, Faigenbaum et al. [32] found no differences between VJ at 10 minutes post warm up and baseline which the present study found as well.

**Power Output**

The results of the present study extend upon previous findings [23, 28] and showed peak power to be highest immediately following both 3 minutes (4.8%) and 6 minutes (3.0%) of a dynamic warm up. Peak power was unable to remain increased at 10 minutes post warm up (WU1: 2.9% and WU2: 0.2%) and was significantly decreased following the CON condition at 20 minutes post condition (-3.6%). Similar to peak power, average power significantly increased immediately following both 3 minutes (5.5%) and 6 minutes (6.5%) of a dynamic warm up, which was highest among the post warm up time periods. Furthermore, average power decrease from 0 minutes to 10 minutes post WU2 (1.2%), but remained significantly greater following 3 minutes of a dynamic warm up at 10 minutes post condition (3.8%). Further decreases in average power occurred from 10 minutes to 20 minutes post warm up for both volumes. While no other studies have examined the influence of recovery duration on power, Faigenbaum et al. [32] experienced reductions in VJ at 14, 18, and 22 minutes post warm up, while Needham et al. [17] found improvements in VJ at both 3 minutes and 6 minutes post dynamic warm up.

**Flexibility**

The results of the present study showed hamstring flexibility was highest immediately following both volumes of the dynamic warm up (WU1: 5.9% and WU2: 7.5%). These values decreased at 10 minutes post warm up for both volumes (WU1: 2.6%), however the 6 minute warm up still maintained increased flexibility above baseline measures (4.4%). At 20 minutes post test, hamstring flexibility was no longer significantly greater than baseline. There were no increases in hip flexor flexibility following either volumes of the dynamic warm up. The 6 minute warm up did have a significant decrease in flexibility at 20 minutes post warm up, with no other differences among the warm up at any time periods. Ryan et al. [9] found musculotendinous stiffness to remain decreased up 10 minutes following 4 minutes of passive stretching; however there is no evidence of the influence dynamic stretching may have on musculotendinous stiffness. The following study found increases in hamstring flexibility which is consistent with previous literature which has found increases in sit and reach flexibility following 6 minutes and 12 minutes of a dynamic warm up [28].

**Balance**

The results of the present study extend upon previous findings [30] and suggest a decrease balance contacts from measure to measure, but not due to any of the warm up conditions. Further results did show a 1.1% decrease in balance ability (contacts) immediately following 6 minutes of a dynamic warm up. Balance time significantly increased following 3 minutes of a dynamic warm up immediately following the warm up (6.7%), and then again at 20 minutes post warm up (9.5%). Further results suggest that no other conditions had an effect on balance scores. While Behm et al. [30] found a 2.2% decrease in balance scores following static stretching, the current study found a 6.7% improvement in balance time immediately following a 3 minute dynamic warm up and an 11.4% improvement in the number of balance contacts after 10 minutes of recovery following a 6 minute dynamic warm up. The stretched induced changes that occur following static stretching may have an effect on muscle output and balance [30], however the current study found slight improvements in balance following 3 minutes of a dynamic warm up, but following 6 minutes of a dynamic warm up balance was hindered immediately following the warm up. Costa et al. [31] found reductions in dynamic balance performance following longer durations of static stretching, which may further elude to the stretch induce changes examined following static stretching that may not occur following dynamic stretching.

**Discussion**

Several factors may account for the discrepancies between the results of the present study and previous research. Herda et al. [10] suggests static stretching may elicit a stretch induced force deficit due to both mechanical and neural factors present in the muscle. This change in the muscle may not occur following dynamic stretching, which may be more beneficial in improving force generating activities. Furthermore, Herda et al. [10] also suggests that an increase in muscle temperature may have an effect on the rigidity of the contractile tissues. The participants in the present study were recreationally trained individuals (RTI), exercising on an average of 6.9 hours per week. Training status seems to be the main difference between the current study and previous studies that have no changes in performance. Both Khorasani et al. [42] and Sekir et al. [38] have suggested that more experienced athletes may show a better adaptation from dynamic stretching than lesser trained individuals. The amount of time spent exercising the current sample may be larger than normal recreationally trained individuals, thus explaining the performance changes seen in the current study. Differences between the current study and the results obtained by Faigenbaum et al. [25] may be due to training status.

Another main mechanism that may present following dynamic stretching is the phenomena of postactivation potentiation (PAP) [52]. Tillin et al. [53] describes PAP as a potentiating affect that occurs following a conditioning response. PAP involves a structural change in the myosin regulatory light chains' ability to accept Ca+ in the muscle cell [53]. PAP has also been affected by the depressed Hoffmann reflex (H-reflex) which involves the afferent nerve fibers involved in the peripheral nervous system [54]. Several studies utilizing dynamic warm ups or stretching have cited PAP as a potential mechanism for the improvements found [24, 25, 51]. It has been suggested by Chiu et al. [55] that competitive athletes have a more positive response to the mechanisms of PAP than recreationally trained individuals and recovery duration following a potentiating stimulus may not induce PAP in recreationally trained individuals [56]. PAP has been suggested to have its greatest affect between 8-12 minutes of recovery following the conditioning [57, 58]. This time frame allows for optimal potentiation to occur while also allowing for fatigue brought on by the conditioning response to decrease enough so that a positive effect occurs [57, 58]. The present study found decreases or no changes occurring at 10 minutes post warm up in VJ height and power output. With previous research suggesting that heavier loads are needed to induce a PAP response [57]. The dynamic warm up may not be a load heavy enough to induce a PAP response in recreationally trained individuals.

Another main factor involved in stretching and warm up is the increase in muscle and core temperature. While the present study did not measure muscle temperature or core temperature, either of these mechanism may have been present which could explain the improvements in performance. Fletcher [14] found increases in HR, suggesting an increase in metabolic effects and vasodilatory tone which may contribute to temperature changes in the body. Again Fletcher & Anness [7] found increases in core temperature and HR following a bout of dynamic stretching which further suggests an increase in blood flow and nerve conduction velocity that may be present in the muscle and may have contributed to the improvements in VJ and power found in the present study, while Bishop [5] has suggested temperature changes in the muscle to enhance performance following a warm up.

Other studies have suggested that measurement familiarization may account for some adaptation seen in VJ performance. Individuals that have completed VJ testing and are familiar with the actions involved may have better improvements following a dynamic warm up than those less trained with a task [20]. While the current study used RTI, participants performed the VJ trials during a familiarization session and the current study manipulated jumping differences by having all participants jump the exact same way. A similar theory proposed by several studies [8, 20, 43] involves the rehearsal of movement during the dynamic warm up. As participants perform the exercises in the dynamic warm up they are rehearsing the similar movements performed during the VJ testing, thus a proprioceptive response may be elicited. This theory has also been suggested by Gergley et al. [40] in which golf swing performance may have been affected by the familiarization with the swing itself, noting that individuals without golf swing experience may not have improvements in performance following dynamic stretching activities due to the specialization of the activity.

An advantage of dynamic stretching includes the capability of changing the speed at which the exercises are performed. One study has shown dynamic stretches performed at faster speeds to elicit greater increases in VJ [16]. The current study performed three high intensity exercises requiring fast contractions of the muscles at the end of the dynamic warm up. These exercises could have induced changes similar to Fletcher & Columbo [14] and Fletcher [16] due to faster movement speeds. The speed and intensity of contractions may affect the PAP response [53] and stretch shortening cycle (SSC) which is a major component of explosive activities and plyometric training [59]. These factors may further explain the results found in the present study.

Flexibility may be affected by several factors. One notable factor that occurs following static stretching is the decrease in musculotendinous stiffness [9, 60]. While the current study found increases in hamstring flexibility following a dynamic warm up, unlike flexibility increases with static stretching, the increases in flexibility did not induce any performance detriments in regards to VJ ability or power output. Ryan et al [28] and Curry et al. [29] also found improvements in flexibility following a dynamic warm up routine using different measures of flexibility (sit & reach and hip flexor). The improvements in VJ and power along with the improvements in flexibility suggest that dynamic stretching may be more beneficial for improving all round performance instead of static stretching. Behm et al. [30] and Costa et al. [31] found changes in balance following static stretching. These studies have shown that proprioception which may be an important contributor to balance and could be also be important in muscle strength and athletic performance [61].

In summary, core temperature, PAP, rehearsal of movement, and training status seem to be the most important factors in contributing the improvements in performance following dynamic warm ups. While the current study did not measure core temperature or PAP, the participants were completing exercises that could be considered rehearsing the performance measurements. Although, the participants were RTI, the amount of exercises performed per week was relatively high, which could account for some of the improvement in performance which is linked to individuals with a higher training status adapting greater to a dynamic warm up stimulus.

While Bishop [1] suggests the warm up activity should last approximately 5-10 minutes, the current study found increases in performance just following 3 minutes of a dynamic warm up, which can further add to the literature. Furthermore, Bishop [1] suggests that athletes and exercisers should rest at least 5 minutes following a warm up and no longer than 20 minutes which by that time, all improvements may be lost. The current study validates the latter part of this suggestion; however improvements in performance were highest immediately following both volumes of the warm up. A limitation to this study may be the extended time period between testing sessions. The results of the present study may suggest something different if measurements were taken at different time periods following the warm ups. Overall, 3-6 minutes of a dynamic warm up is sufficient time to elicit improvements in VJ, muscle power, and flexibility immediately following the warm up, however decreases in performance may be seen after 10 minutes of rest and all improvements will be lost after 20 minutes of rest.

# CHAPTER VI

# CONCLUSION

This study adds to the literature involving warm up design. The present study suggests that both 3 minutes and 6 minutes of a dynamic warm up routine which increases in intensity may improve VJ, power output, and flexibility. The improvements in VJ, power output, and flexibility are only present for a short period of time, and are decreased by 10 minutes post warm up and for the most part, are similar to pre warm up values at 20 minutes post warm up. Balance may slightly decrease following 6 minutes of a dynamic warm up, however balance improves over the course of testing periods.

Future research should examine different rest periods other than 0, 10, and 20 minutes post warm up, as there may be difference found at some time period in between those periods. Other studies could also examine the exercises performed during the dynamic warm up as the ones used may not have elicited to greatest improvements. Further research could also investigate not just the recovery duration, but what type of recovery may elicit changes in performance (i.e. passive vs. active recovery). Finally, further research should examine more effects that dynamic warm ups may have on flexibility and balance as this was the first study to examine the influence of a dynamic warm up on balance performance.

# PRACTICAL APPLICATION

Strength & conditioning professionals and coaches have more knowledge regarding the appropriate length of a dynamic warm up and the appropriate recovery period needed to improve performance. This knowledge may further enhance strength training programs and practice routines so that coaches may draw greater improvements in an athlete's talent. Health professionals may also use this current study as valuable information to help clients design a better pre workout routine in hopes of inducing greater gains through training and better performances in competition.

# RECOMMENDATION

Individuals or athletes seeking to improve performance should take note of the following: perform a pre activity warm up that consists of a 5 minute light aerobic activity followed by dynamic stretching exercises for approximately 3-6 minutes. Perform whatever activity immediately following the pre event warm up. Athletes should not rest more than 10 minutes following the warm up to in order to optimize performance during the activity or competition.

# REFERENCES

1. Bishop, D., *Warm up II: performance changes following active warm up and how to structure the warm up.* Sports Med, 2003. **33**(7): p. 483-98.
2. High, D.M., E.T. Howley, and B.D. Franks, *The Effects of Static Stretching and Warm-up on Prevention of Delayed-Onset Muscle Soreness.* Research Quarterly for Exercise and Sport, 1989. **60**(4): p. 357-361.
3. Shellock, F.G. and W.E. Prentice, *Warming-up and stretching for improved physical performance and prevention of sports-related injuries.* Sports Med, 1985. **2**(4): p. 267-78.
4. Smith, C.A., *The warm-up procedure: to stretch or not to stretch. A brief review.* J Orthop Sports Phys Ther, 1994. **19**(1): p. 12-7.
5. Bishop, D., *Warm up I: potential mechanisms and the effects of passive warm up on exercise performance.* Sports Med, 2003. **33**(6): p. 439-54.
6. Faigenbaum, A.D., et al., *Acute effects of different warm-up protocols on fitness performance in children.* J Strength Cond Res, 2005. **19**(2): p. 376-81.
7. Fletcher, I.M. and R. Anness, *The acute effects of combined static and dynamic stretch protocols on fifty-meter sprint performance in track-and-field athletes.* J Strength Cond Res, 2007. **21**(3): p. 784-7.

8. Fletcher, I.M. and B. Jones, *The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players.* J Strength Cond Res, 2004. **18**(4): p. 885-8.

9. Ryan, E.D., et al., *The Time Course of Musculotendinous Stiffness Responses Following Different Durations of Passive Stretching.* Journal of Orthopaedic & Sports Physical Therapy, 2008. **38**(10): p. 632-639.

10. Herda, T.J., et al., *Acute effects of static versus dynamic stretching on isometric peak torque, electromyography, and mechanomyography of the biceps femoris muscle.* J Strength Cond Res, 2008. **22**(3): p. 809-17.

11. Bandy, W.D., J.M. Irion, and M. Briggler, *The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles.* J Orthop Sports Phys Ther, 1998. **27**(4): p. 295-300.

12. Chattong, C., et al., *Effect of a dynamic loaded warm-up on vertical jump performance.* J Strength Cond Res. **24**(7): p. 1751-4.

13. Hough, P.A., E.Z. Ross, and G. Howatson, *Effects of dynamic and static stretching on vertical jump performance and electromyographic activity.* J Strength Cond Res, 2009. **23**(2): p. 507-12.

14. Fletcher, I.M. and M.M. Monte-Colombo, *An investigation into the possible physiological mechanisms associated with changes in performance related to acute responses to different preactivity stretch modalities.* Appl Physiol Nutr Metab, 2010. **35**(1): p. 27-34.

15. Holt, B.W. and K. Lambourne, *The impact of different warm-up protocols on vertical jump performance in male collegiate athletes.* J Strength Cond Res, 2008. **22**(1): p. 226-9.

16. Fletcher, I.M., *The effect of different dynamic stretch velocities on jump performance.* Eur J Appl Physiol, 2010. **109**(3): p. 491-498.

17. Needham, R.A., C.I. Morse, and H. Degens, *The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players.* J Strength Cond Res, 2009. **23**(9): p. 2614-20.

18. Thompsen, A.G., et al., *Acute effects of different warm-up protocols with and without a weighted vest on jumping performance in athletic women.* J Strength Cond Res, 2007. **21**(1): p. 52-6.

19. Christensen, B.K. and B.J. Nordstrom, *The effects of proprioceptive neuromuscular facilitation and dynamic stretching techniques on vertical jump performance.* J Strength Cond Res, 2008. **22**(6): p. 1826-31.

20. Dalrymple, K.J., et al., *Effect of static and dynamic stretching on vertical jump performance in collegiate women volleyball players.* J Strength Cond Res, 2010. **24**(1): p. 149-55.

21. Jaggers, J.R., et al., *The acute effects of dynamic and ballistic stretching on vertical jump height, force, and power.* J Strength Cond Res, 2008. **22**(6): p. 1844-9.

22. Judge, L.W., et al., *An Examination of the Stretching Practices of Division I and Division Iii College Football Programs in the Midwestern United States.* Journal of Strength and Conditioning Research, 2009. **23**(4): p. 1091-1096.

23. Yamaguchi, T. and K. Ishii, *Effects of static stretching for 30 seconds and dynamic stretching on leg extension power*. J Strength Cond Res, 2005. **19**(3): p. 677-83.

24. Yamaguchi, T., et al., *Acute effects of dynamic stretching exercise on power output during concentric dynamic constant external resistance leg extension.* J Strength Cond Res, 2007. **21**(4): p. 1238-44.

25. Faigenbaum, A.D., et al., *Dynamic warm-up protocols, with and without a weighted vest, and fitness performance in high school female athletes.* J Athl Train, 2006. **41**(4): p. 357-63.

26. O'Sullivan, K., E. Murray, and D. Sainsbury, *The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects.* BMC Musculoskelet Disord, 2009. **10**: p. 37.

27. Thacker, S.B., Gilchrist, J., Stroup, D.F. and Kimsey, C.D., *The Impact of Stretching on Sports Injury Risk: A Systematic Review of the Literature.* Med. Sci. Sports Exerc, 2004. **36**(3): p. 371-378.

28. Ryan, E.D., Everett, K.L., Smith, D.B., Pollner, C., Thompson, B.J., Fiddler, R.E., *The effect of different volumes of a dynamic warm-up on human performance.* Journal of Applied Physiology, Nutrition, and Metabolism, 2010. **In review**.

29. Curry, B.S., et al., *Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women.* J Strength Cond Res, 2009. **23**(6): p. 1811-9.

30. Behm, D.G., et al., *Effect of acute static stretching on force, balance, reaction time, and movement time.* Med Sci Sports Exerc, 2004. **36**(8): p. 1397-402.

31. Costa, P.B., et al., *The Acute Effects of Different Durations of Static Stretching on Dynamic Balance Performance.* Journal of Strength and Conditioning Research, 2009. **23**(1): p. 141-147.

32. Faigenbaum, A.D., et al., *Influence of recovery time on warm-up effects in male adolescent athletes.* Pediatr Exerc Sci, 2010. **22**(2): p. 266-77.

33. Church, J.B., et al., *Effect of warm-up and flexibility treatments on vertical jump performance.* Journal of Strength and Conditioning Research, 2001. **15**(3): p. 332-336.

34. Baechle, T.R., R.W. Earle, and National Strength & Conditioning Association (U.S.), *Essentials of strength training and conditioning*. 3rd ed. 2008, Champaign, IL: Human Kinetics. xiv, 641 p.

35. Williford, H.N., et al., *Evaluation of Warm-up for Improvement in Flexibility.* American Journal of Sports Medicine, 1986. **14**(4): p. 316-319.

36. Little, T. and A.G. Williams, *Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players.* J Strength Cond Res, 2006. **20**(1): p. 203-7.

37. Taylor, K.L., et al., *Negative effect of static stretching restored when combined with a sport specific warm-up component.* J Sci Med Sport, 2009. **12**(6): p. 657-61.

38. Sekir, U., et al., *Acute effects of static and dynamic stretching on leg flexor and extensor isokinetic strength in elite women athletes.* Scand J Med Sci Sports, 2010. **20**(2): p. 268-281.

39. Manoel, M.E., et al., *Acute effects of static, dynamic, and proprioceptive neuromuscular facilitation stretching on muscle power in women.* J Strength Cond Res, 2008. **22**(5): p. 1528-34.

40. Gergley, J.C., *Acute effects of passive static stretching during warm-up on driver clubhead speed, distance, accuracy, and consistent ball contact in young male competitive golfers.* J Strength Cond Res, 2009. **23**(3): p. 863-7.

41. McMillian, D.J., et al., *Dynamic vs. static-stretching warm up: the effect on power and agility performance.* J Strength Cond Res, 2006. **20**(3): p. 492-9.

42. Khorasani, M.A., et al., *Acute Effect of Different Stretching Methods on Illinois Agility Test in Soccer Players.* J Strength Cond Res, 2010. **0**(0): p. 1-7.

43. Moran, K.A., et al., *Dynamic stretching and golf swing performance.* Int J Sports Med, 2009. **30**(2): p. 113-8.

44. Ferber, R., K.D. Kendall, and L. McElroy, *Normative and critical criteria for iliotibial band and iliopsoas muscle flexibility.* J Athl Train, 2010. **45**(4): p. 344-8.

45. Walsh, J. and T. Hall, *Agreement and correlation between the straight leg raise and slump tests in subjects with leg pain.* J Manipulative Physiol Ther, 2009. **32**(3): p. 184-92.

46. Leard, J.S., et al., *Validity of two alternative systems for measuring vertical jump height.* Journal of Strength and Conditioning Research, 2007. **21**(4): p. 1296-1299.

47. Rhea, M.R., et al., *An examination of training on the VertiMax resisted jumping device for improvements in lower body power in highly trained college athletes.* J Strength Cond Res, 2008. **22**(3): p. 735-40.

48. Jennings, C.L., et al., *The reliability of the FitroDyne as a measure of muscle power.* J Strength Cond Res, 2005. **19**(4): p. 859-63.

49. Fredrick, G.A. and D.J. Szymanski, *Baseball (Part I): Dynamic flexibility.* Strength and Conditioning Journal, 2001. **23**(1): p. 21-30.

50. Rhea, M.R., *Determining the magnitude of treatment effects in strength training research through the use of the effect size.* Journal of Strength and Conditioning Research, 2004. **18**(4): p. 918-920.

51. Chaouachi, A., et al., *Effect of warm-ups involving static or dynamic stretching on agility, sprinting, and jumping performance in trained individuals.* J Strength Cond Res, 2010. **24**(8): p. 2001-11.

52. Sale, D.G., *Postactivation potentiation: Role in human performance.* Exercise and Sport Sciences Reviews, 2002. **30**(3): p. 138-143.

53. Tillin, N.A. and D. Bishop, *Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities.* Sports Med, 2009. **39**(2): p. 147-66.

54. Hamada, T., et al., *Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles.* Journal of Applied Physiology, 2000. **88**(6): p. 2131-2137.

55. Chiu, L.Z.F., et al., *Postactivation potentiation response in athletic and recreationally trained individuals.* Journal of Strength and Conditioning Research, 2003. **17**(4): p. 671-677.

56. Jo, E., et al., *Influence of Recovery Duration after a Potentiating Stimulus on Muscular Power in Recreationally Trained Individuals.* Journal of Strength and Conditioning Research, 2010. **24**(2): p. 343-347.

57. Tillin, N.A. and D. Bishop, *Factors Modulating Post-Activation Potentiation and its Effect on Performance of Subsequent Explosive Activities.* Sports Medicine, 2009. **39**(2): p. 147-166.

58. Kilduff, L.P., et al., *Postactivation potentiation in professional rugby players: Optimal recovery.* Journal of Strength and Conditioning Research, 2007. **21**(4): p. 1134-1138.

59. Bosco, C., I. Tarkka, and P.V. Komi, *Effect of Elastic Energy and Myoelectrical Potentiation of Triceps Surae during Stretch-Shortening Cycle Exercise.* International Journal of Sports Medicine, 1982. **3**(3): p. 137-140.

60. Ryan, E.D., et al., *Determining the minimum number of passive stretches necessary to alter musculotendinous stiffness.* Journal of Sports Sciences, 2009. **27**(9): p. 957-961.

61. Blackburn, T., et al., *Balance and joint stability: The relative contributions of proprioception and muscular strength.* Journal of Sport Rehabilitation, 2000. **9**(4): p. 315-328.

FIGURES

## Figure 1. Hamstring Flexibility Results

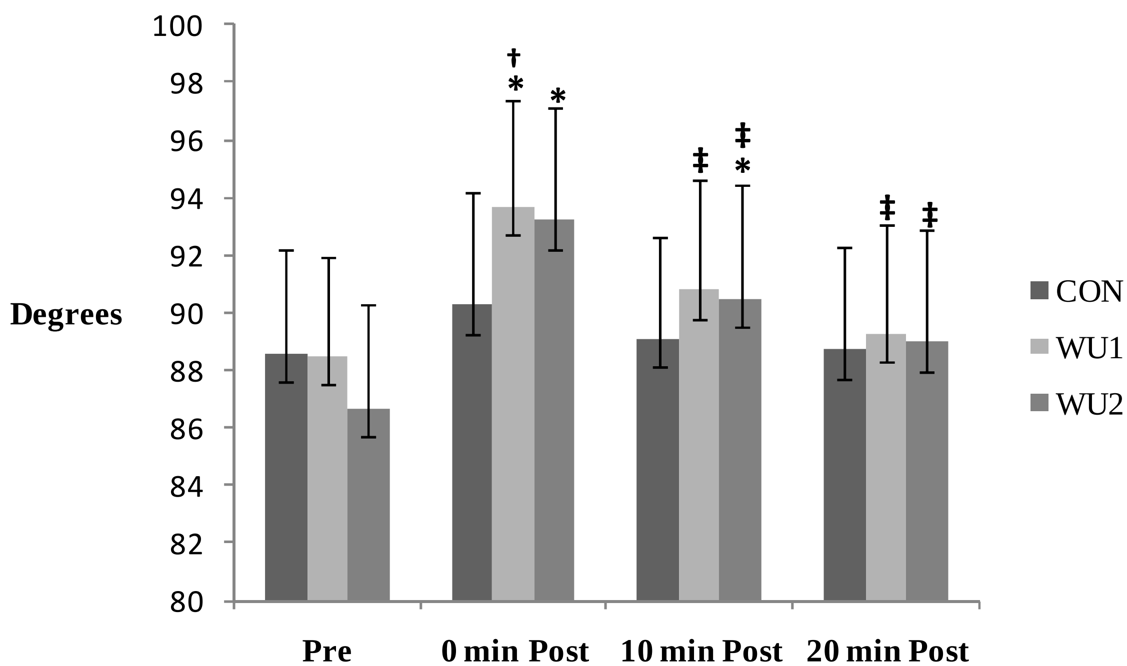
Pre and post warm up mean (SE) values for hamstring flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Hamstring Flexibility (degrees) | | | | |
|---|---|---|---|---|
| Condition | Pre | 0 min Post | 10 min Post | 20 min Post |
| CON | 88.6 (3.57) | 90.3 (3.86) | 89.1 (3.53) | 88.7 (3.61) |
| WU1 | 88.5 (3.46) | 93.7 (3.72)*† | 90.8 (3.80)‡ | 89.3 (3.74)‡ |
| WU2 | 86.7 (3.55) | 93.2 (3.89)* | 90.5 (3.99)*‡ | 89.0 (3.86)‡ |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

† indicates a significant ($P \leq 0.05$) difference from CON condition

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up




* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

† indicates a significant ($P \leq 0.05$) difference from CON condition

‡ indicates a significant ($P \leq 0.05$) difference from immediate post warm up

**Figure 2. Hamstring Flexibility Interaction Graph**

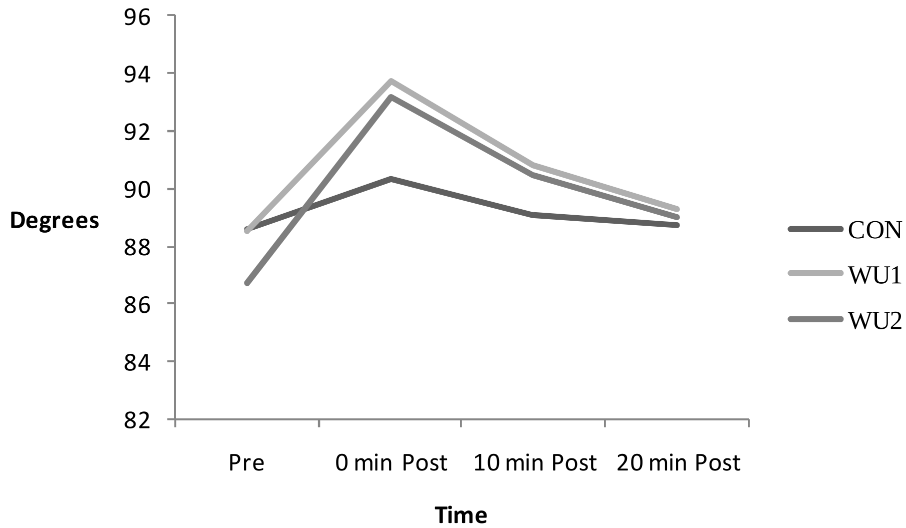


**Figure 3. Hamstring Flexibility Percent Change**

Percent change values from baseline for hamstring flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Hamstring Flexibility (degrees) | | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | 1.92% | 0.56% | 0.11% |
| WU1 | 5.87% | 2.60% | 0.90% |
| WU2 | 7.50% | 4.38% | 2.65% |

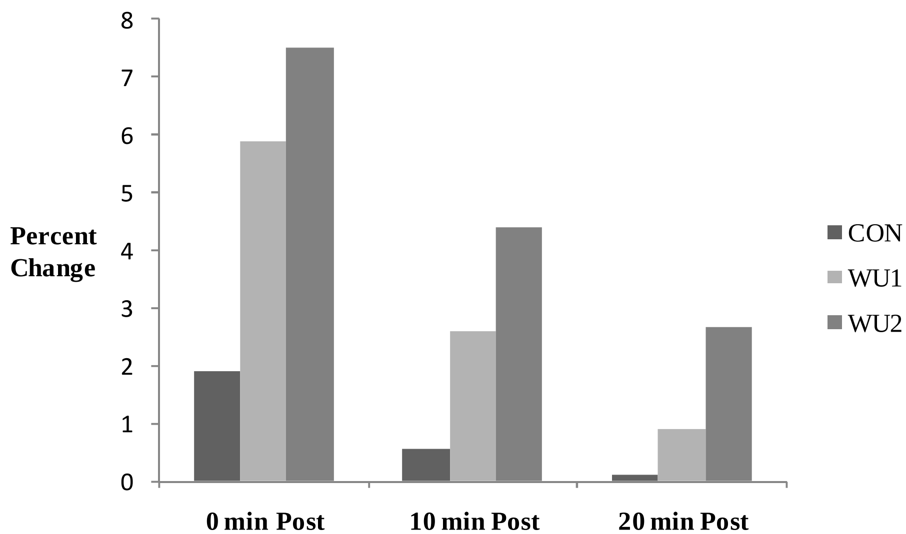


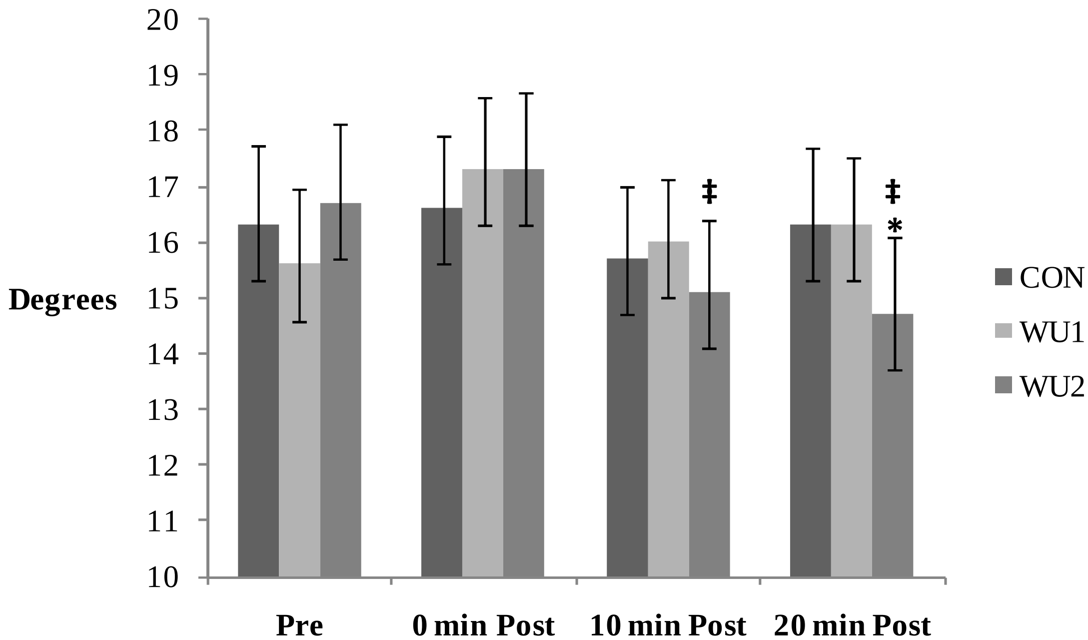
**Figure 4. Hip Flexor Flexibility Results**

Pre and post warm up mean (SE) values for hip flexor flexibilityof the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Thomas Test (degrees) | | | | |
|---|---|---|---|---|
| Condition | Pre | 0 min Post | 10 min Post | 20 min Post |
| CON | 16.3 (1.46) | 16.6 (1.32) | 15.7 (1.32) | 16.3 (1.40) |
| WU1 | 15.6 (1.36) | 17.3 (1.32) | 16.0 (1.13) | 16.3 (1.23) |
| WU2 | 16.7 (1.44) | 17.3 (1.38) | 15.1 (1.30)‡ | 14.7 (1.38)*‡ |

* indicates a significant (P ≤ 0.05) difference from pre to post treatment

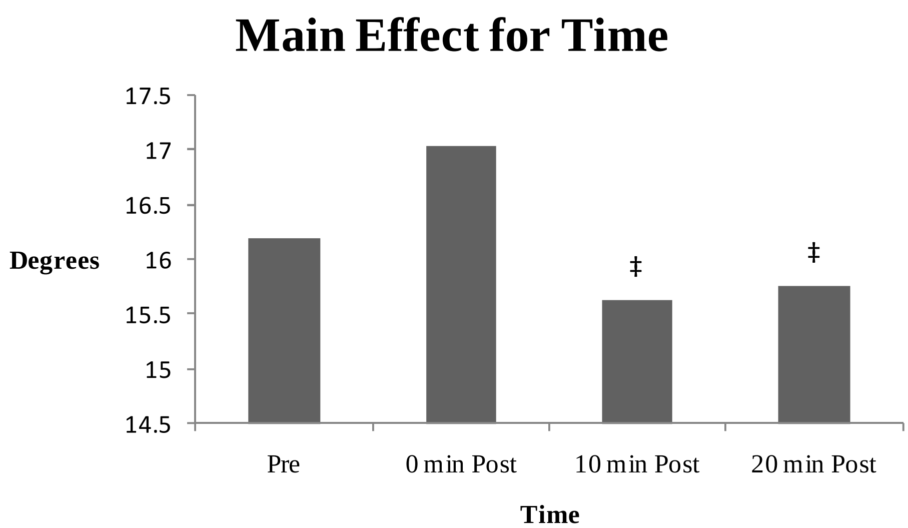
‡ indicates a significant (P ≤ 0.05) difference from 0 min post warm up




* indicates a significant (P ≤ 0.05) difference from pre to post treatment

‡ indicates a significant (P ≤ 0.05) difference from immediate post warm up

**Figure 5. Hip Flexor Flexibility Marginal Means**




‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

**Figure 6. Hip Flexor Flexibility Percent Change**

Percent change values from baseline for hip flexor flexibility of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Thomas Test | | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | 1.84% | -3.68% | 0.00% |
| WU1 | 10.90% | 2.56% | 4.49% |
| WU2 | 3.59% | -9.58% | -11.98% |

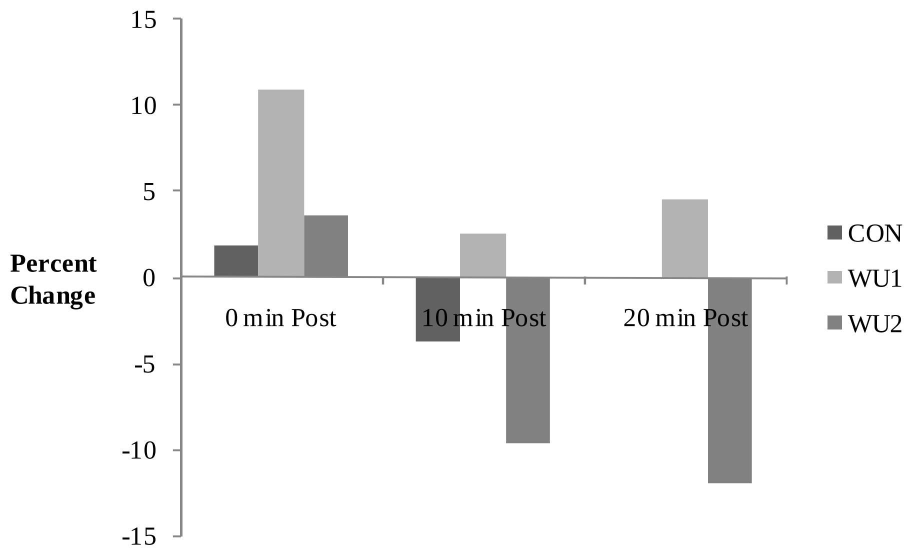


**Figure 7. Vertical Jump Results**

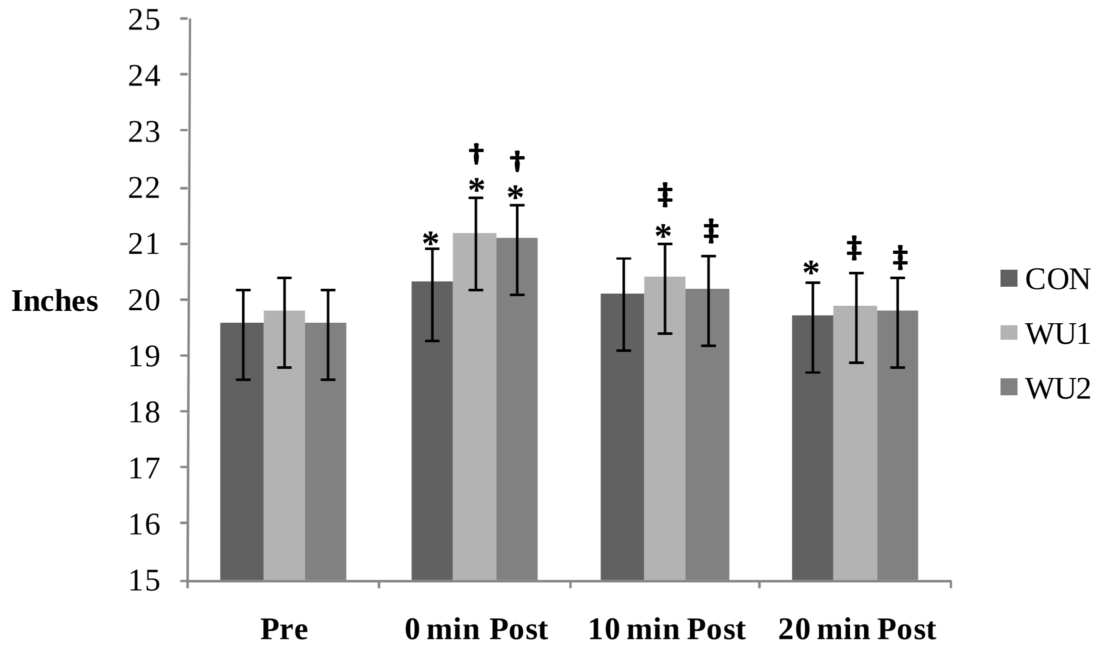
Pre and post warm up mean (SE) values for the vertical jump test of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | | Vertical Jump (inches) | | |
|---|---|---|---|---|
| Condition | Pre | 0 min Post | 10 min Post | 20 min Post |
| CON | 19.6 (0.60) | 20.3 (0.60)* | 20.1 (0.64) | 19.7 (0.62)* |
| WU1 | 19.8 (0.62) | 21.2 (0.64)*† | 20.4 (0.60)*‡ | 19.9 (0.59)‡ |
| WU2 | 19.6 (0.59) | 21.1 (0.59)*† | 20.2 (0.60)‡ | 19.8 (0.60)‡ |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

† indicates a significant ($P \leq 0.05$) difference from CON condition

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

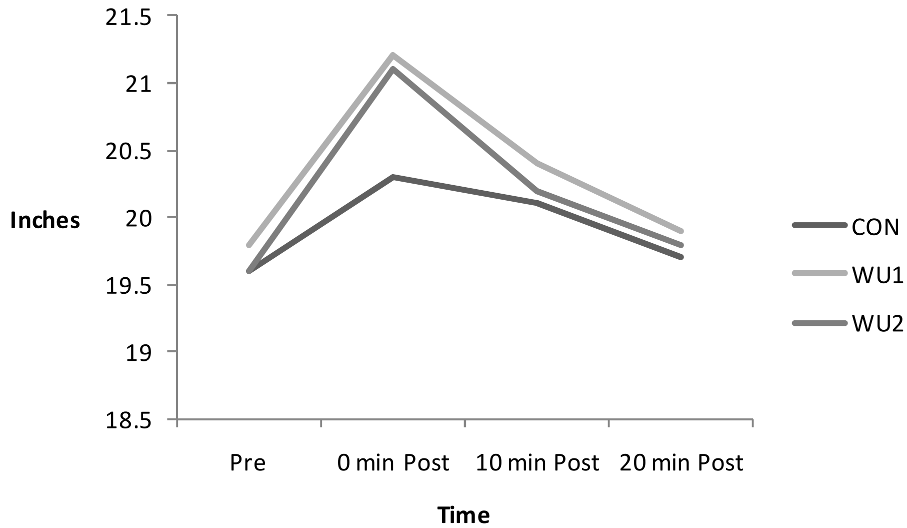



* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

† indicates a significant ($P \leq 0.05$) difference from CON condition

‡ indicates a significant ($P \leq 0.05$) difference from immediate post warm up

**Figure 8. Vertical Jump Interaction Graph**



## Figure 9. Vertical Jump Percent Change

Percent change values from baseline for vertical jump of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Vertical Jump (inches) | | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | 3.57% | 2.55% | 0.51% |
| WU1 | 7.07% | 3.03% | 0.51% |
| WU2 | 7.65% | 3.06% | 1.02% |

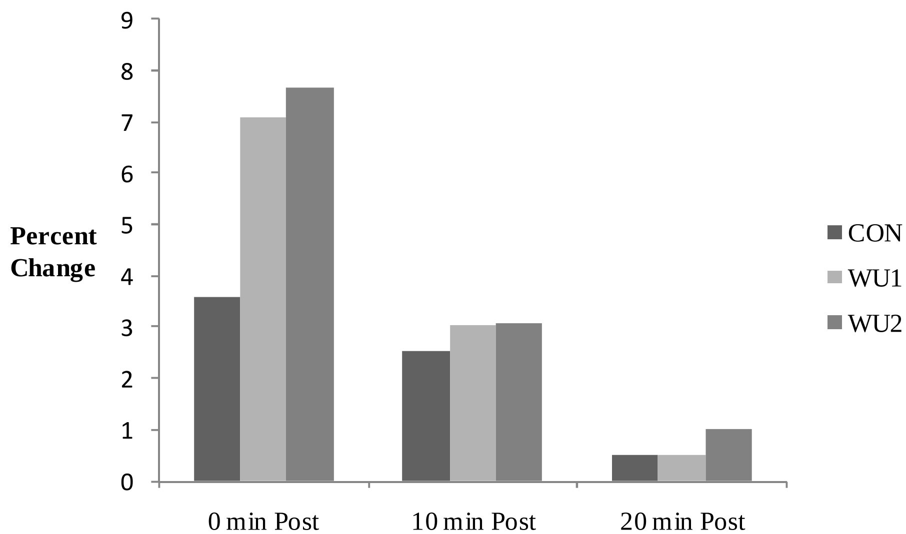


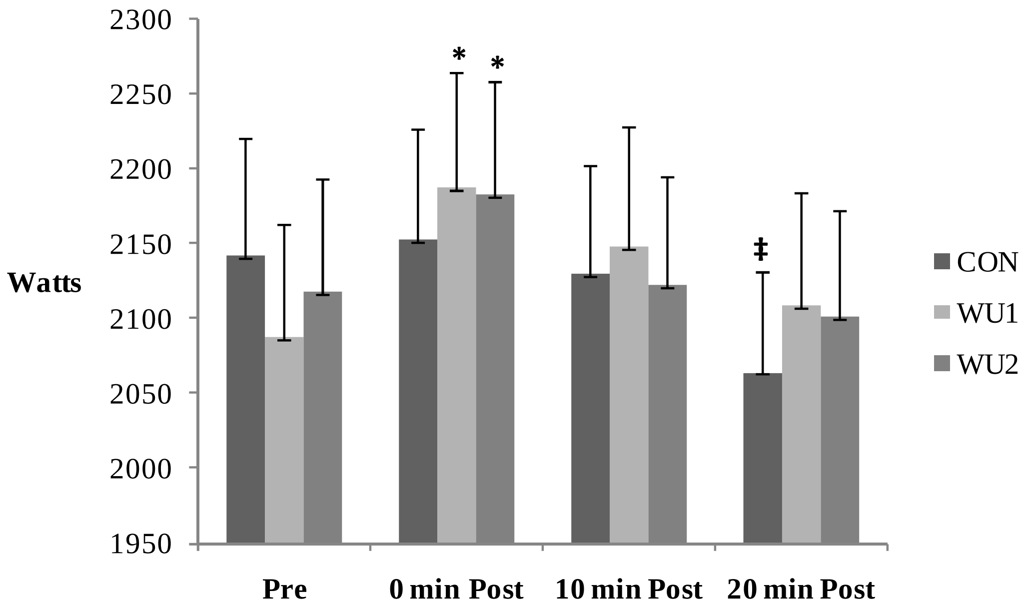
**Figure 10. Peak Power Results**

Pre and post warm up mean (SE) values for peak power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Peak Power (watts) | | | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 2142.2 (75.31) | 2152.6 (74.84) | 2130.0 (73.12) | 2064.2 (68.05)‡ |
| WU1 | 2087.5 (76.37) | 2187.4 (77.80)* | 2147.8 (81.02) | 2108.7 (75.27) |
| WU2 | 2117.9 (75.52) | 2183.0 (75.63)* | 2121.9 (73.85) | 2101.0 (71.45) |

* indicates a significant (P ≤ 0.05) difference from pre to post treatment

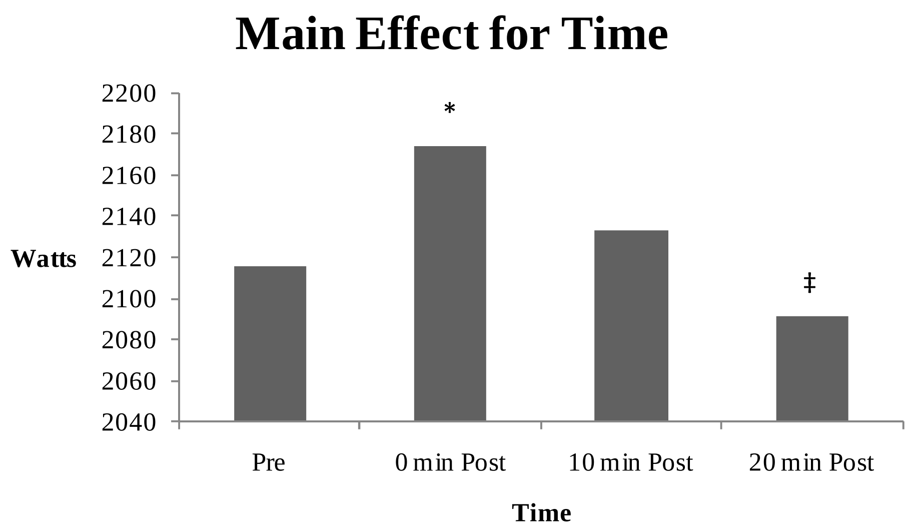
‡ indicates a significant (P ≤ 0.05) difference from 0 min post warm up




* indicates a significant (P ≤ 0.05) difference from pre to post treatment

‡ indicates a significant (P ≤ 0.05) difference from immediate post warm up

**Figure 11. Peak Power Marginal Means**

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* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

**Figure 12. Peak Power Percent Change**

Percent change values from baseline for peak power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Peak Power (watts) | | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | 0.49% | -0.57% | -3.64% |
| WU1 | 4.79% | 2.89% | 1.02% |
| WU2 | 3.07% | 0.19% | -0.80% |

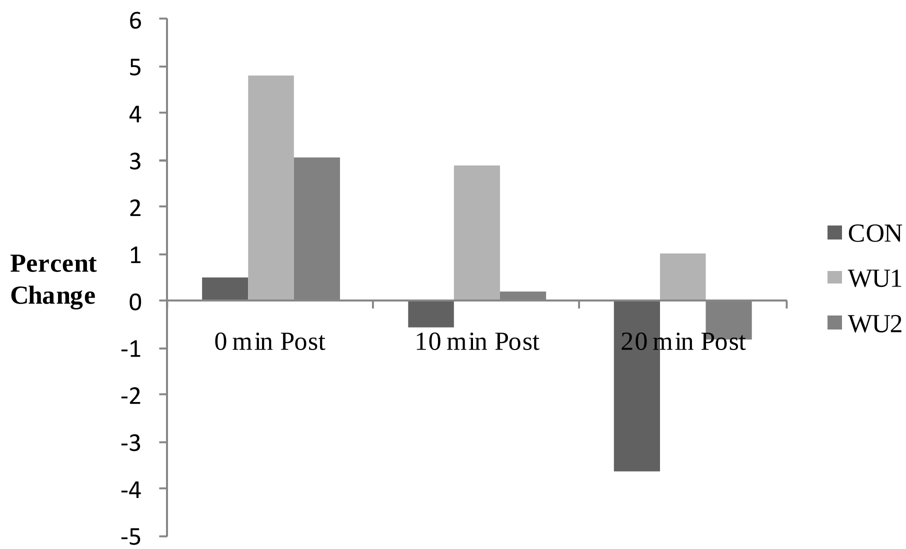


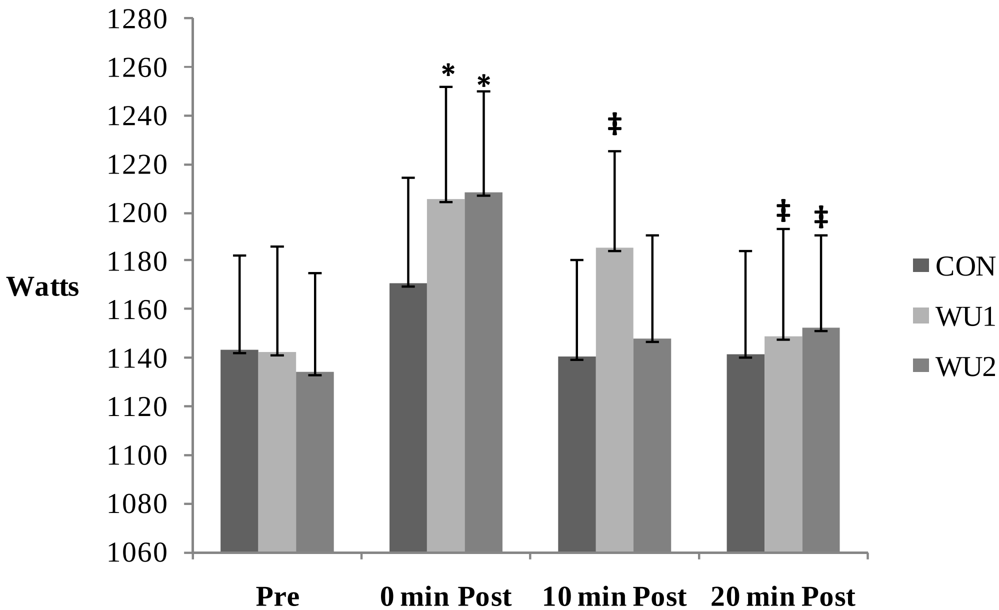
**Figure 13. Average Power Results**

Pre and post warm up mean (SE) values for average power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | Average Power (watts) | | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 1143.3 (39.52) | 1171.1 (43.48) | 1140.9 (39.80) | 1141.6 (42.80) |
| WU1 | 1142.5 (43.81) | 1205.2 (46.94)* | 1185.4 (39.97) | 1149.0 (44.26)‡ |
| WU2 | 1134.3 (40.63) | 1208.2 (42.62)* | 1148.2 (42.37)‡ | 1152.2 (38.68)‡ |

* indicates a significant (P ≤ 0.05) difference from pre to post treatment

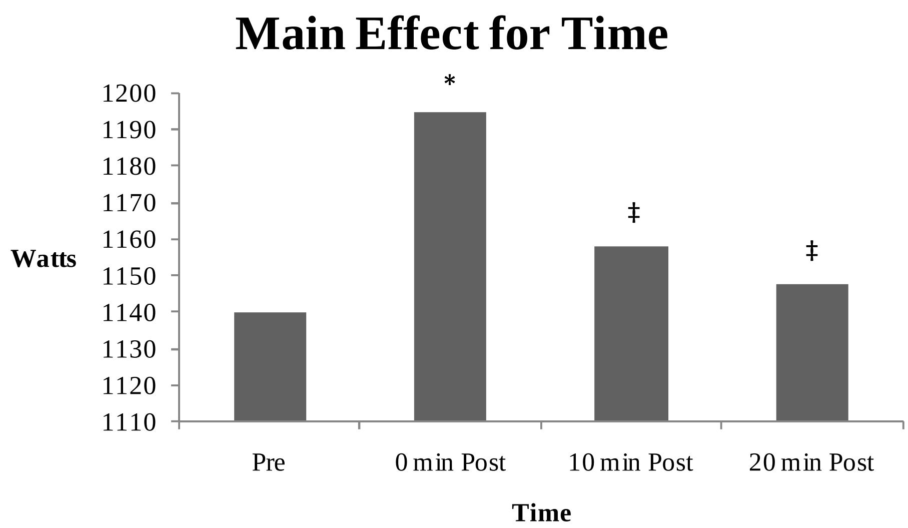
‡ indicates a significant (P ≤ 0.05) difference from 0 min post warm up




* indicates a significant (P ≤ 0.05) difference from pre to post treatment

‡ indicates a significant (P ≤ 0.05) difference from immediate post warm up

**Figure 14. Average Power Marginal Means**




* indicates a significant ($P \leq 0.05$) difference from pre to post treatment
‡ indicates a significant ($P \leq 0.05$) difference from 0 min post warm up

**Figure 15. Average Power Percent Change**

Percent change values from baseline for average power of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | Average Power (watts) | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | 2.43% | -0.21% | -0.15% |
| WU1 | 5.49% | 3.75% | 0.57% |
| WU2 | 6.52% | 1.23% | 1.58% |

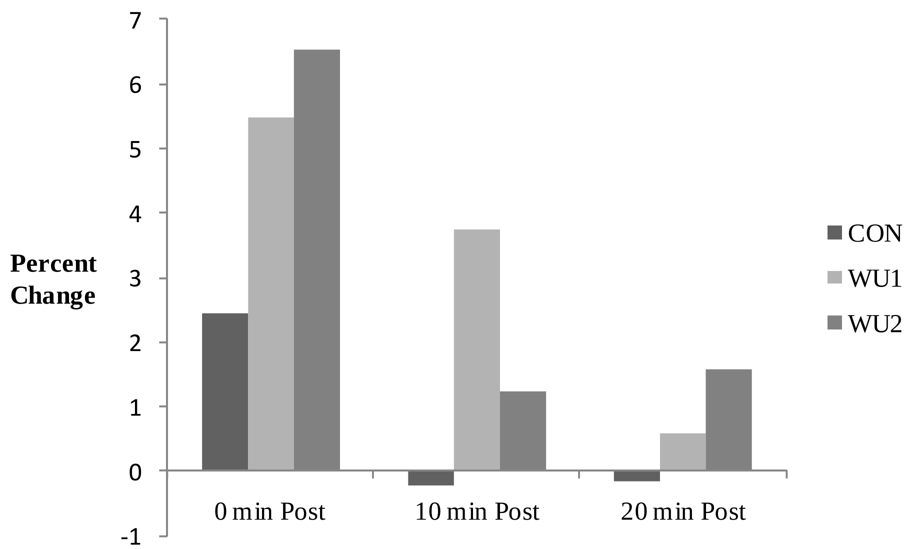


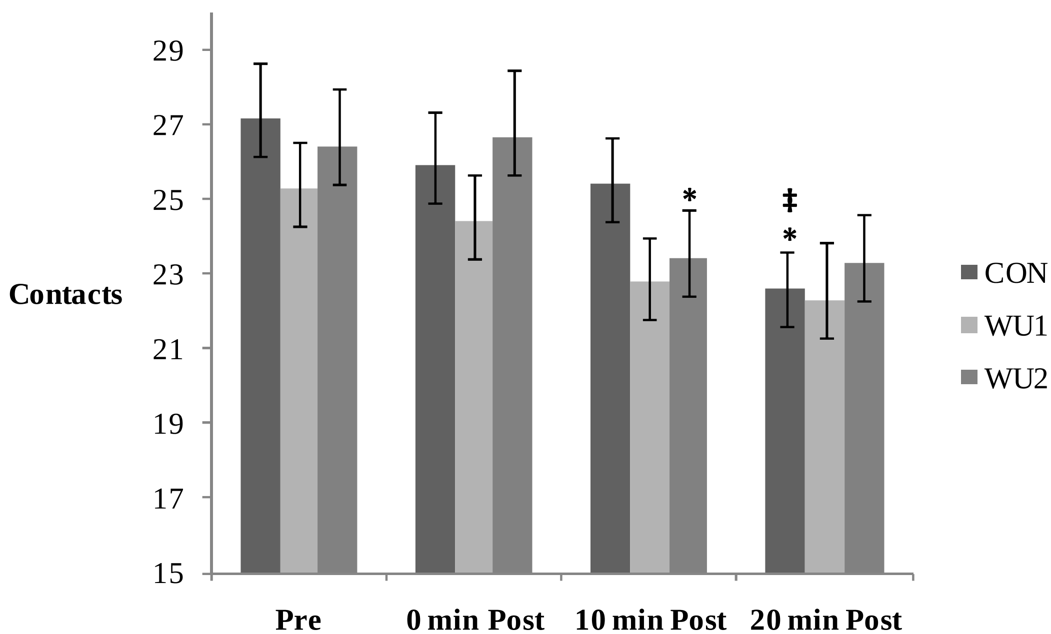
**Figure 16. Balance Contacts Results**

Pre and post warm up mean (SE) values for balance contacts of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| | **Balance Contacts** | | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 27.2 (1.46) | 25.9 (1.44) | 25.4 (1.29) | 22.6 (1.02)*‡ |
| WU1 | 25.3 (1.25) | 24.4 (1.25) | 22.8 (1.21) | 22.3 (1.59) |
| WU2 | 26.4 (1.59) | 26.7 (1.78) | 23.4 (1.34)* | 23.3 (1.30) |

* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

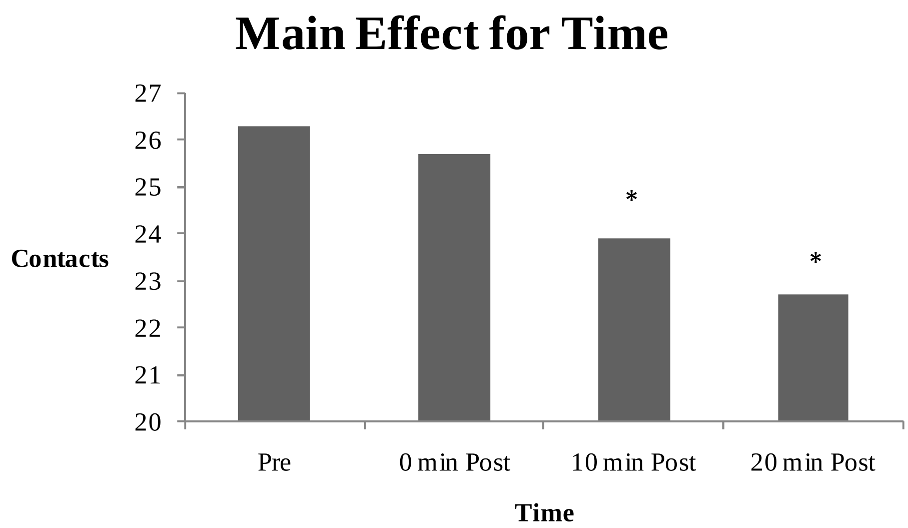
‡ indicates a significant ($P \leq 0.05$) difference from immediate post warm up




* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

‡ indicates a significant ($P \leq 0.05$) difference from immediate post warm up

**Figure 17. Balance Contacts Marginal Means**




* indicates a significant ($P \leq 0.05$) difference from pre to post treatment

**Figure 18. Balance Contacts Percent Change**

Percent change values from baseline for balance contacts of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

| Balance Contacts | | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | -4.78% | -6.62% | -16.91% |
| WU1 | -3.56% | -9.89% | -11.86% |
| WU2 | 1.14% | -11.36% | -11.74% |

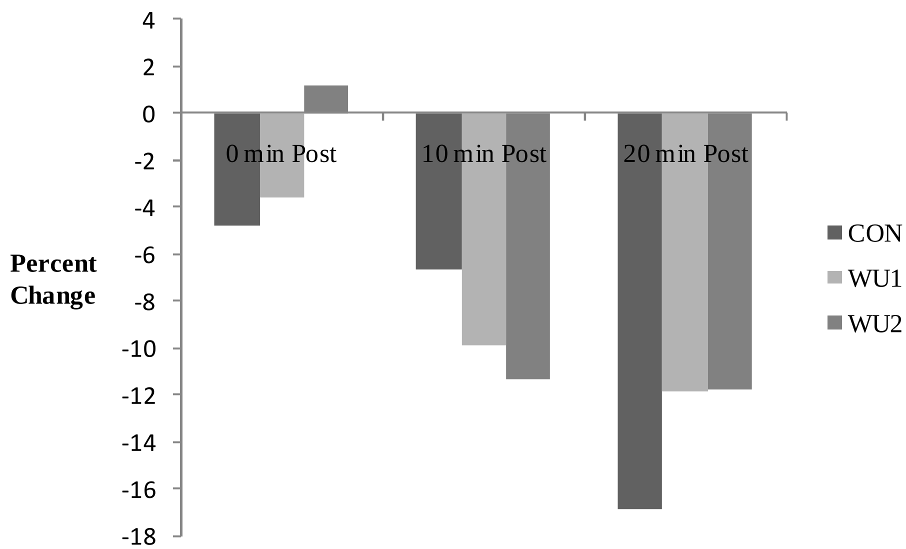
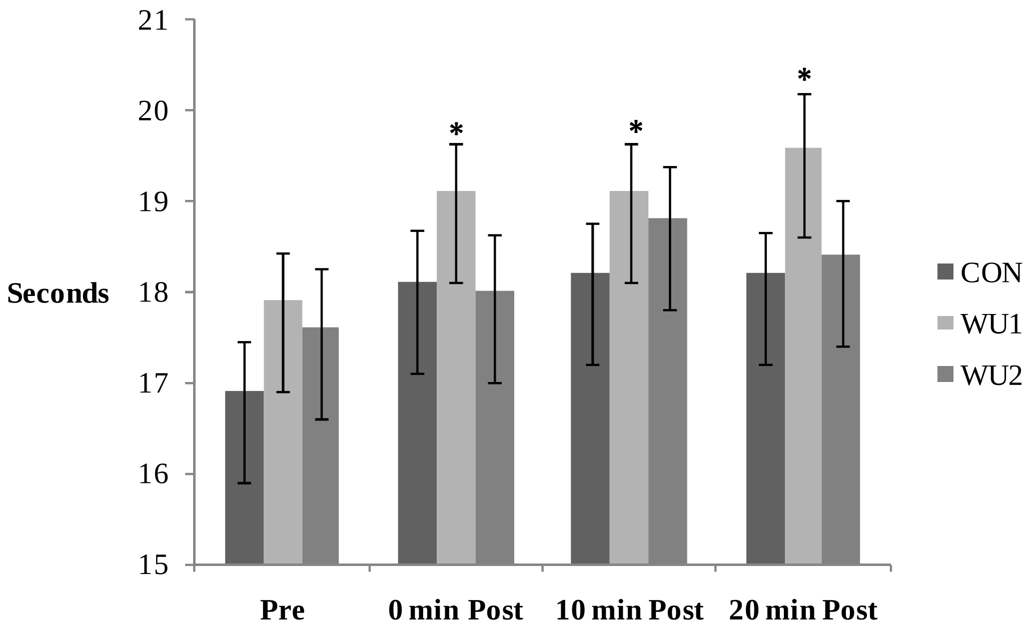


**Figure 19. Balance Time Results**

Pre and post warm up mean (SE) values for balance time of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

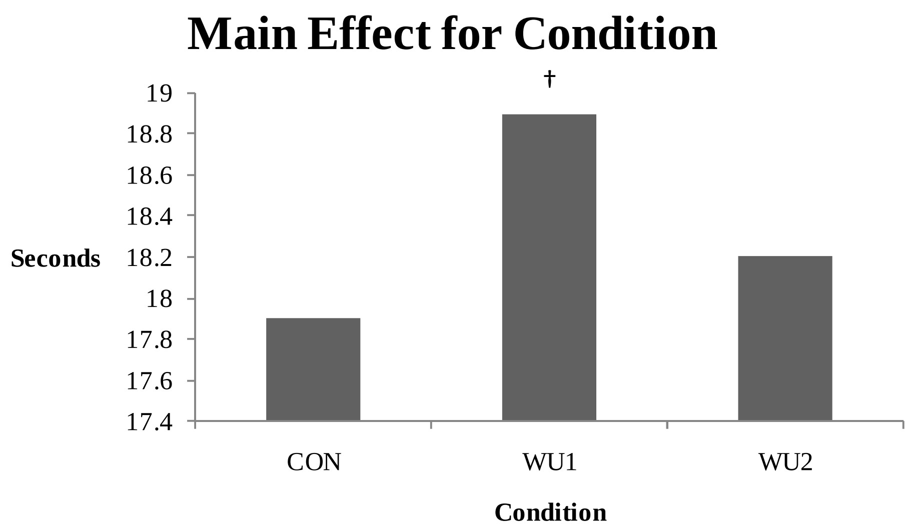
| | Balance Time (seconds) | | | |
|---|---|---|---|---|
| Condition | Pre test | 0 min Post | 10 min Post | 20 min Post |
| CON | 16.9 (0.57) | 18.1 (0.59) | 18.2 (0.57) | 18.2 (0.45) |
| WU1 | 17.9 (0.53) | 19.1 (0.55)* | 19.1 (0.53) | 19.6 (0.59)* |
| WU2 | 17.6 (0.66) | 18.0 (0.64) | 18.8 (0.59)* | 18.4 (0.60) |

* indicates a significant (P ≤ 0.05) difference from pre to post treatment

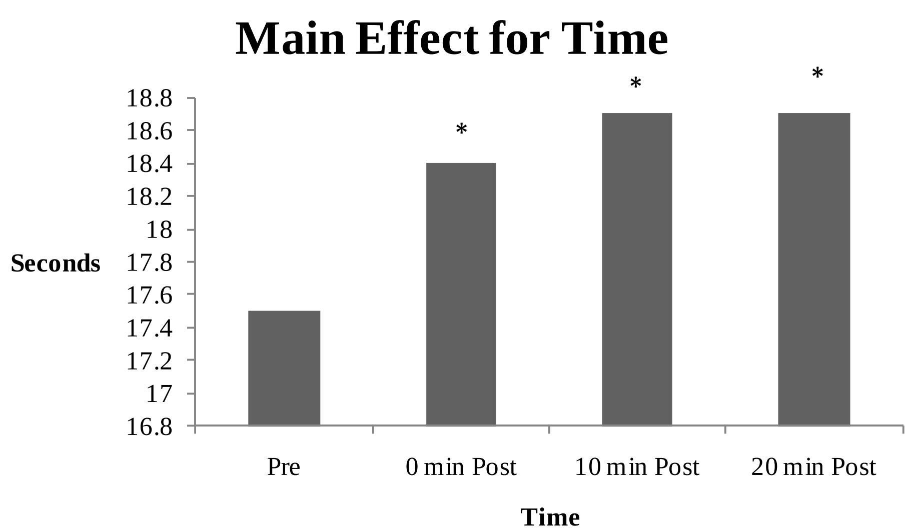



* indicates a significant (P ≤ 0.05) difference from pre to post treatment

**Figure 20. Balance Time Marginal Means**




† indicates a significant (P ≤ 0.05) difference from CON condition

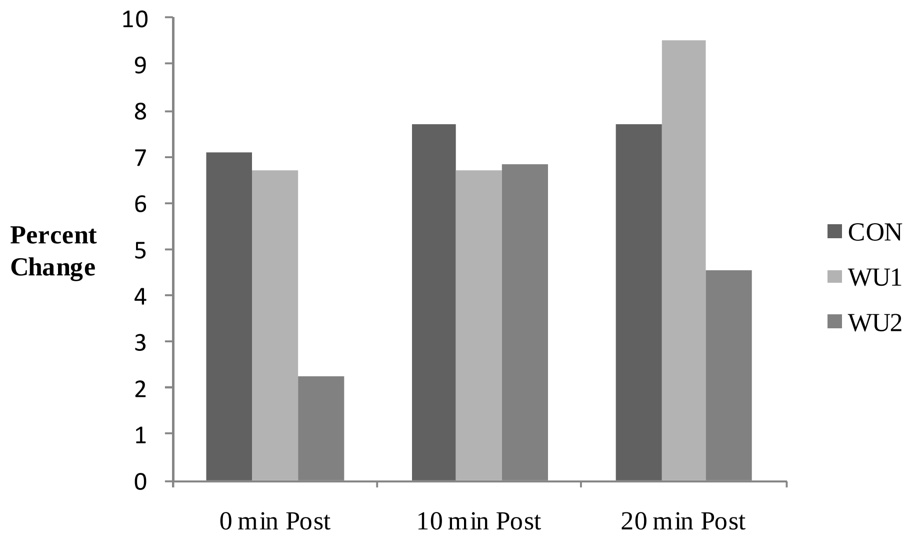



* indicates a significant (P ≤ 0.05) difference from pre to post treatment

**Figure 21. Balance Time Percent Change**

Percent change values from baseline for balance time of the control (CON), warm up 1 (WU1), and warm up 2 (WU2) conditions.

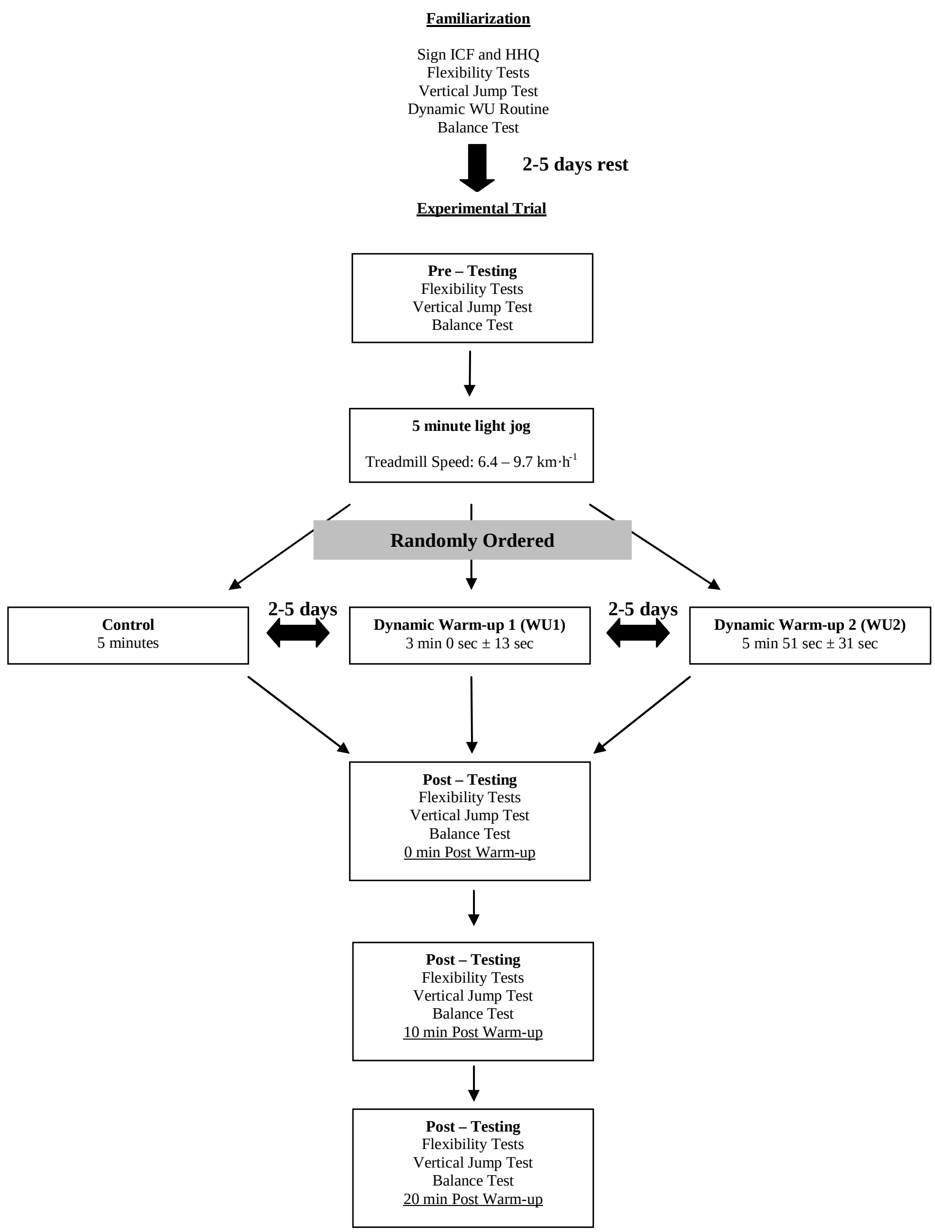
| Balance Time (seconds) | | | |
|---|---|---|---|
| Condition | 0 min Post | 10 min Post | 20 min Post |
| CON | 7.10% | 7.69% | 7.69% |
| WU1 | 6.70% | 6.70% | 9.50% |
| WU2 | 2.27% | 6.82% | 4.55% |



# APPENDICES

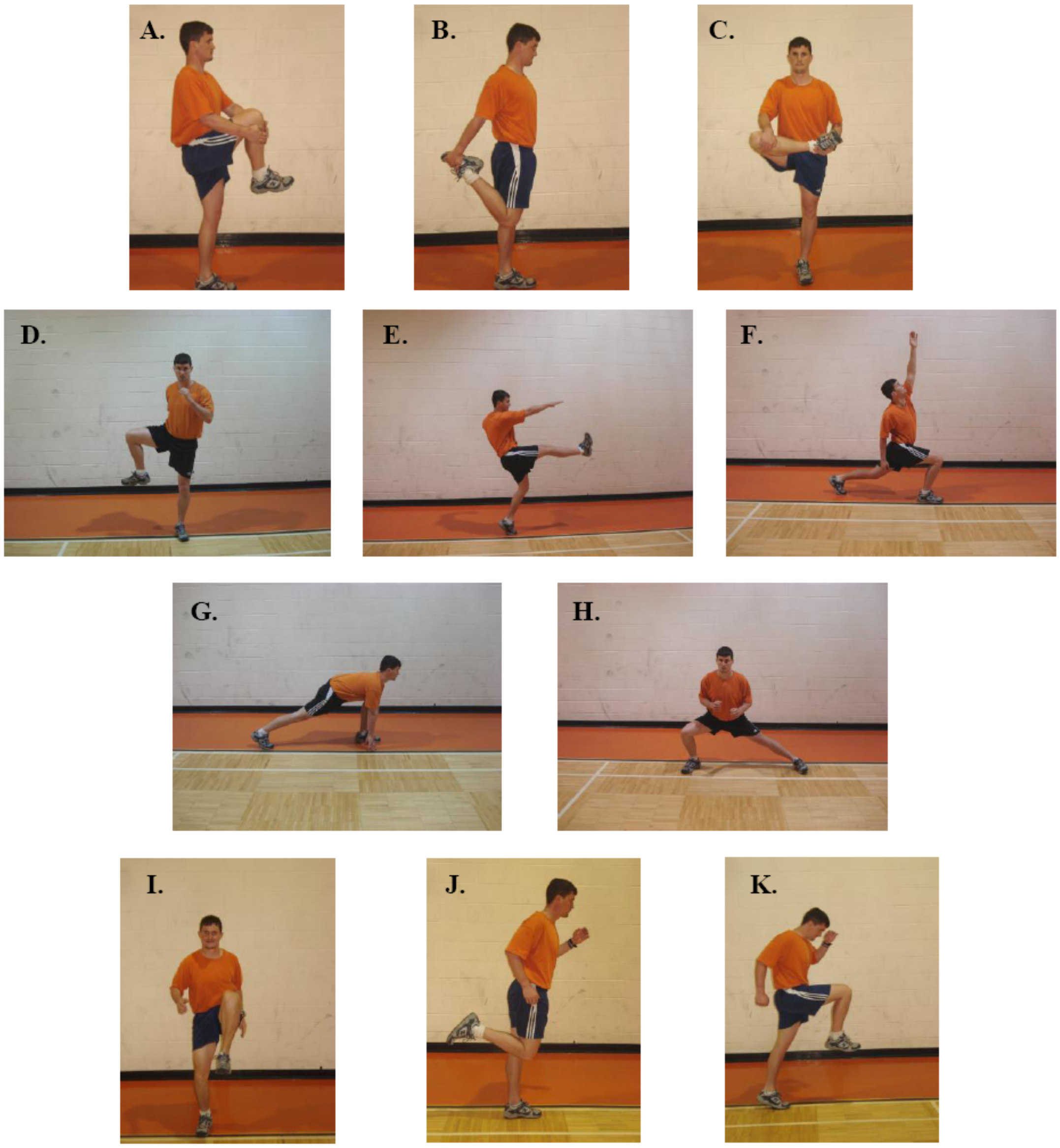
## APPENDIX A

## RESEARCH DESIGN



APPENDIX B

DYNAMIC WARM UP EXERCISES



APPENDIX C

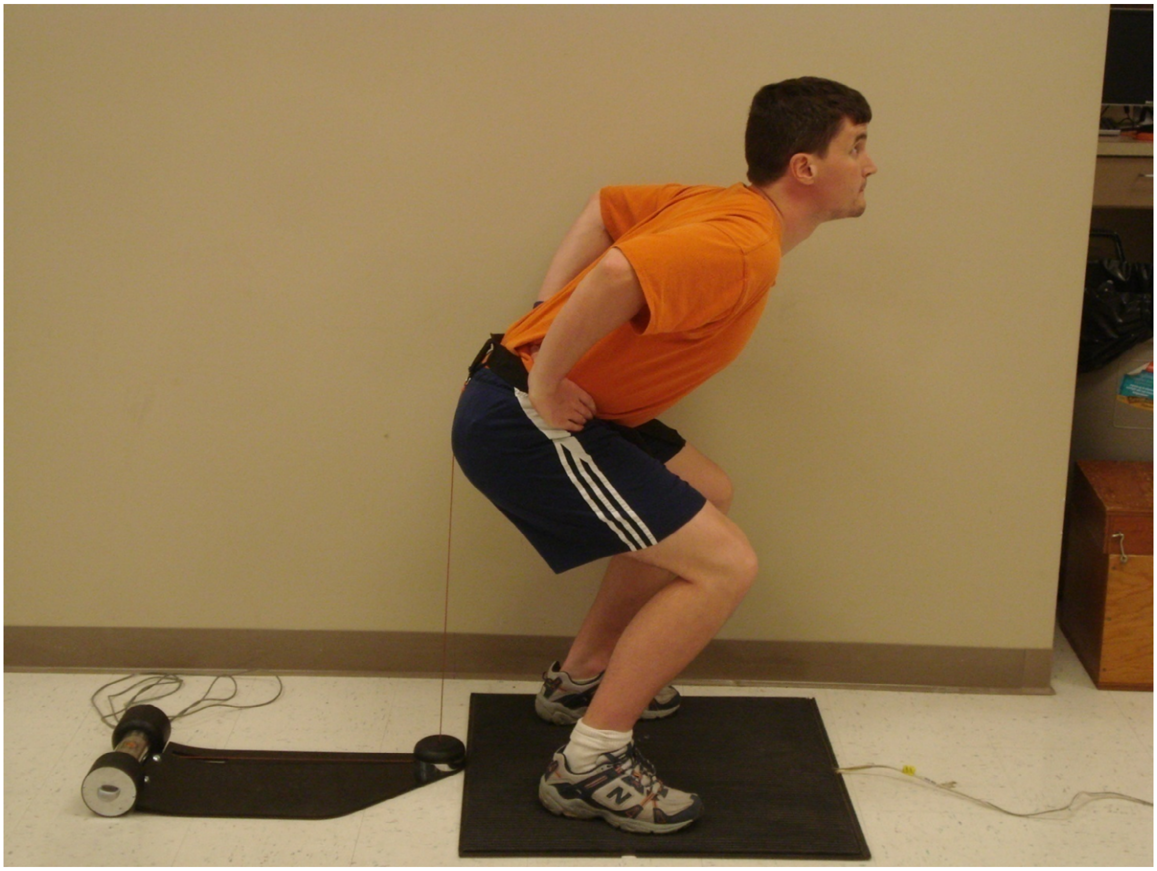
HIP FLEXOR FLEXIBILTIY ASSESSMENT

APPENDIX D

HAMSTRING FLEXIBILITY ASSESSMENT

APPENDIX E

VERTICAL JUMP & POWER ASSESSMENT



APPENDIX F

BALANCE ASSESSMENT

APPENDIX G

# HEALTH HISTORY QUESTIONNAIRE

**PRE-EXERCISE TESTING HEALTH & EXERCISE STATUS QUESTIONNAIRE**

HEALTH AND HUMAN PERFORMANCE DEPARTMENT

Participant ID ______________________________________________ Date_____________

Cell Phone_______________ Other Phone_______________

Home Address____________________________________

Person to contact in case of emergency _________________________________________

Emergency Contact Phone _____________________ Birthday (mm/dd/yy)____/_____/_____

Personal Physician ___________________________ Physician's Phone______________

Gender ____ Age ____(yrs) Height (self report) ____(ft)____(in) Weight (self report) ____(lbs)

Does the above weight indicate: a gain____ a loss____ no change____ in the past 6 months?
If a change, how many pounds?__________(lbs)

**A. JOINT-MUSCLE STATUS** (✓Check areas where you currently have problems)

Joint Areas
( ) Wrists
( ) Elbows
( ) Shoulders
( ) Upper Spine & Neck
( ) Lower Spine
( ) Hips
( ) Knees
( ) Ankles
( ) Feet
( ) Other_____________________

Muscle Areas
( ) Arms
( ) Shoulders
( ) Chest
( ) Upper Back & Neck
( ) Abdominal Regions
( ) Lower Back
( ) Buttocks
( ) Thighs
( ) Lower Leg
( ) Feet
( ) Other___________________

**B. HEALTH STATUS** (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Edema
( ) Epilepsy
( ) Multiply Sclerosis
( ) High Blood Cholesterol or Triglyceride Levels
( ) Allergic reactions to rubbing alcohol

( ) Acute Infection
( ) Diabetes or Blood Sugar Level Abnormality
( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction
( ) Pancreas Dysfunction
( ) Liver Dysfunction
( ) Kidney Dysfunction
( ) Phenylketonuria (PKU)
( ) Loss of Consciousness

* *NOTE: If any of these conditions are checked, then a physician's health clearance may be required.*

**C. PHYSICAL EXAMINATION HISTORY**

Approximate date of your last physical examination______________________________

Physical problems noted at that time__________________________________________

Has a physician ever made any recommendations relative to limiting your level of physical exertion? _________YES __________NO

If YES, what limitations were recommended?___________________________________

_________________________________________________________________________

**D. CURRENT MEDICATION USAGE** (List the drug name and the condition being managed)

| MEDICATION | CONDITION |
|---|---|
| __________________________ | ____________________________________ |
| __________________________ | ____________________________________ |
| __________________________ | ____________________________________ |

**E. PHYSICAL PERCEPTIONS** (Indicate any unusual sensations or perceptions. ✓Check if you have recently experienced any of the following during or soon after *physical activity* (PA); or during *sedentary periods* (SED))

| PA | SED | | PA | SED | |
|---|---|---|---|---|---|
| ( ) | ( ) | Chest Pain | ( ) | ( ) | Nausea |
| ( ) | ( ) | Heart Palpitations | ( ) | ( ) | Light Headedness |
| ( ) | ( ) | Unusually Rapid Breathing | ( ) | ( ) | Loss of Consciousness |
| ( ) | ( ) | Overheating | ( ) | ( ) | Loss of Balance |
| ( ) | ( ) | Muscle Cramping | ( ) | ( ) | Loss of Coordination |
| ( ) | ( ) | Muscle Pain | ( ) | ( ) | Extreme Weakness |
| ( ) | ( ) | Joint Pain | ( ) | ( ) | Numbness |
| ( ) | ( ) | Other_______________________ | ( ) | ( ) | Mental Confusion |

**F. FAMILY HISTORY** (✓Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes
( ) Sudden Death (other than accidental)

**G. EXERCISE STATUS** (Please provide a precise estimation of your previous exercise habits)

**Do you regularly engage in aerobic forms of exercise (i.e., jogging, cycling, walking, etc.)? YES NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many *hours per week* do you spend for this type of exercise? _______ hours

**Do you regularly lift weights? YES NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many *hours per week* do you spend for this type of exercise? _______ hours

**Do you regularly play recreational sports (i.e., basketball, racquetball, volleyball, etc.)? YES NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many *hours per week* do you spend for this type of exercise? _______ hours

**PRE-EXERCISE TESTING HEALTH & EXERCISE STATUS QUESTIONNAIRE EXCLUSION CRITERIA**

HEALTH AND HUMAN PERFORMANCE DEPARTMENT

Subject ID________________________________ Date______________

EXCLUSION CRITERIA:

1. Participants have indicated they have current (within the past 3 months) joint-muscle problems with their lower back, hips, legs, knees, ankles and or feet that would not allow them to complete the testing.
2. If they have a specific health condition that would not allow them to complete the testing.
3. They exercise more than 10 hours per week.

APPENDIX H

IRB APPROVAL

## Oklahoma State University Institutional Review Board

| | |
|---|---|
| Date: | Wednesday, September 29, 2010 |
| IRB Application No | ED10120 |
| Proposal Title: | The Influence of Recovery Time Following various Volumes of a Dynamic Warm-up on Human Performance in Recreationally Active Males |
| Reviewed and Processed as: | Expedited |

**Status Recommended by Reviewer(s): Approved Protocol Expires: 9/28/2011**

Principal Investigator(s):

| | |
|---|---|
| Lee Everett<br>199 Colvin Rec. Center<br>Stillwater, OK 74078 | Douglas Smith<br>197 Colvin Center<br>Stillwater, OK 74078 |

---

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

APPENDIX I

# INFORMED CONSENT FORM

## INFORMED CONSENT FOR PARTICIPATION IN THE STUDY

**Project Title**: The influence of recovery time following various volumes of a dynamic warm-up on human performance in recreationally active males.

**Investigators**: Lee Everett, M.S. & Doug Smith, Ph.D.
School of Applied Health & Educational Psychology
Oklahoma State University

**Purpose**: The type of warm-up procedures performed prior to athletic events has recently come under considerable scrutiny. Therefore, the purpose of the current study is to determine the effectiveness of different rest periods following different volumes of a dynamic warm-up on vertical jump performance, flexibility, muscle power, and balance.

**Procedures**:
As a subject you will visit the lab on 4 occasions. The Health & Human Performance Lab is located in the Colvin Recreation Center (CRC), room 192. During the 1st visit you will complete this form and a Health History & Exercise Status Questionnaire. Following those forms, if you qualify, then you will practice the dynamic warm-up, flexibility, muscle power, and vertical jump tests. During the remaining 3 visits you will randomly perform a 5 min jog on a treadmill, a warm-up lasting about 5 - 10 min long, a warm-up lasting 3-5 minutes, or 10 minutes rest. Before and after these tests we will measure your flexibility, muscle power, balance, and vertical jump performance. The flexibility tests will have you lie on your back while two passive measurements will be made to determine hip flexor and hamstring flexibility. The Vertical Jump and muscle power test will require you to have your feet shoulder-width apart and have you bend your knees at a comfortable position and then jump up as high as you can. The balance test will have you stand on a balance board for 30 seconds. The dynamic warm-up will include exercises designed to warm and stretch your muscles similar to general calisthenics.

**Risks of Participation**: Possible risks include muscle soreness and temporary blood pressure elevation due to muscle contractions. Medical information will only be used during the screening process. In case of injury or illness resulting from this study, emergency medical treatment will be available (CPR certified investigators and 911). No funds have been set aside by Oklahoma State University to compensate you in the event of illness or injury.

**Benefits**: Your participation will help us determine the most optimal warm-up to be performed prior to athletic competition. Your participation will also allow you to answer the following questions about specific physical attributes.

1. **Strength**: How strong are your lower body muscles?
2. **Vertical Jump:** How high can you jump?
3. **Power:** How powerful are you during a vertical jump?
4. **Flexibility**: How flexible are your lower body muscles?
5. **Balance:** How well can your lower body muscles balance your total body?

**Confidentiality**: Confidentiality will be maintained by coding all information with individual identification numbers. The master list will be kept in a locked file cabinet in the PI's (Lee Everett) office. Only qualified research personnel and the Oklahoma State University Institutional Review Board (IRB) will have access to the database containing study information. All study data entered into statistical analyses and publication reports will have no identification to participants. No individual or group other than the research team will be given information, unless specifically requested by the IRB. All primary data sources will be kept in the locked file cabinet located in the PI's office. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research.

**Contacts**: This study has been reviewed and approved by the Oklahoma State University Institutional Review Board (IRB). If you have questions about the research project you may contact Lee Everett at keveret@okstate.edu and/or Doug Smith, Ph.D. at doug.smith@okstate.edu. If you have questions about your rights as a research volunteer, you may contact Dr. Sheila Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

**Participation Rights**: Participation in the study is voluntary and you are free to withdraw completely from the study at any time. There is no penalty for refusal to participate or failure to compete the study.

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy of this informed consent form was given to me.

_______________________________________________ Date:______________

Signature of Participant

I certify that I have personally explained this document before requesting that the participant sign it.

_______________________________________________ Date:______________

Signature of Researcher

APPENDIX J

RECRUITMENT SCRIPT

**HEALTH AND HUMAN PERFORMANCE DEPARTMENT**

Hello,

My name is Lee Everett; I am a doctoral student in the Health and Human Performance Department at Oklahoma State University. I am writing to you regarding a study we are conducting in our laboratory which examines the influence of recovery time on warm-up effects in recreationally active males. We are looking for **male participants between the ages of 18-30 with no current or recent (within the past 3 months) serious low-back, hip, knee, or ankle injuries. These men must also engage in less than 10 hours of physical activity per week.**

**We are trying to determine the influence of recovery time on various warm-up volumes in recreationally active males.**

**<u>What you will receive from the testing:</u>**

**Strength**: How strong your lower body muscles are.
**Vertical Jump:** How high you can jump.
**Power:** How powerful you are during a vertical jump.
**Flexibility**: How flexible your lower body muscles are.
**Balance:** How well your lower body muscle can balance your total body

The study involves only 4 visits to the laboratory! Each visit will take approximately 1 hour each (**4 hours total**).

If you are interested we can be reached at the following:

**Lab phone**: 405-744-9373
**Email: keveret@okstate.edu**
**Fax: 405-744-6507**

THANK YOU FOR YOUR INTEREST, we look forward to hearing from you soon!!

Kind regards,

Lee Everett, M.S., C.S.C.S.
Applied Musculoskeletal & Human Physiology Laboratory
Health & Human Performance Department
Oklahoma State University
E-mail: keveret@okstate.edu

APPENDIX K

RECRUITMENT FLYER

# PRE-EXERCISE WARM-UP STUDY

MALE SUBJECTS WANTED!

**Participants must be between the ages of 18-30. You must be able to perform a vertical jump exercise, sit and reach test, and seated leg press. Additionally, you must not exercise more than 10 hours per week.**

***If you are eligible and interested please contact:***

**Lee Everett**
**CRC 199 (Lab)**
**229-942-0081**
**keveret@okstate.edu**

**Your total time commitment will be a maximum of 4 hours!**

| | | | | |
|---|---|---|---|---|
| **Lee Everett** | **Lee Everett** | **Lee Everett** | **Lee Everett** | **Lee Everett** |
| keveret@okstate.edu | keveret@okstate.edu | keveret@okstate.edu | keveret@okstate.edu | keveret@okstate.edu |
| 229-942-0081 | 229-942-0081 | 229-942-0081 | 229-942-0081 | 229-942-0081 |

# VITA

Kenneth Lee Everett, Jr.

Candidate for the Degree of Doctor of Philosophy

Dissertation: THE INLFUENCE OF RECOVERY TIME FOLLOWING DIFFERENT VOLUMES OFA DYNAMIC WARM UP ON HUMAN PERFORMANCE IN RECREATIONALLY ACTIVE MALES

Major Field: Health, Leisure, & Human Performance

Biographical:

I was born on May 22, 1984 in Americus, GA. I attended Americus high School and graduated as an honor graduate in May 2002. I have two dogs (Riley & Gussie) and love the outdoors.

Education:

Oklahoma State University (OSU), Stillwater, OK
Doctor of Philosophy, May 2011
Health & Human Performance

Georgia Southern University (GSU), Statesboro, GA
Master of Science, May 2008
Kinesiology

Georgia Southwestern State University (GSW), Americus, GA
Bachelor of Science, July 2006
Exercise Science

Experience:

Graduate Associate, Oklahoma State University
August 2008-May 2011

Graduate Assistant, Georgia Southern University
August 2006-May 2008

Professional Memberships:

National Strength & Conditioning Association (2007-Present)
American College of Sports Medicine (2008-Present)

Name: Kenneth Lee Everett, Jr. Date of Degree: May 2011

Institution: Oklahoma State University Location: Stillwater, OK

Title of Study: THE INFLEUNCE OF RECOVERY TIME FOLLOWING DIFFERENT VOLUMES OF A DYNAMIC WARM UP ON HUMAN PERFORMANCE IN RECREATIONALLY ACTIVE MALES

Pages in Study: 117 Candidate for the Degree of Doctor of Philosophy

Major Field: Health, Leisure, & Human Performance


Scope and Method of Study:

The purpose of the present study was to extend upon findings in the literature, examine the acute effects of different volumes of a dynamic warm-up on human performance, and to examine the influence of recovery time following a dynamic warm up on human performance. A convenience sample of 28 recreationally active males [(mean ± SD) age, 21.3 ± 1.4 years; height, 178.0 ± 6.3 cm; weight, 80.9 ± 10.7 kg] completed counterbalanced, within-subjects, repeated measures design (CON x WU1 x WU2). Each subject performed three randomly ordered conditions: a) control (CON), b) a dynamic warm-up routine (WU1), and c) a dynamic warm-up routine with twice the volume of WU1 (WU2). The WU1 condition was performed for 3 minutes ± 13 seconds and the WU2 condition was performed for 5 min 51 sec ± 31 seconds. A 4 x 3 repeated measures ANOVA (time x condition) was used to analyze each of the following dependent variables: VJ height, peak power output, average power output, hip flexor flexibility, hamstring flexibility, and balance [number of ground contacts and total time balanced]. When appropriate, follow-up analyses included one-way repeated measures ANOVA with bonferroni corrected paired-samples *t*-tests. SPSS software (version 17.0, Chicago, IL) was used for all statistical comparisons. An alpha level will be set at $P \leq 0.05$ to determine any statistical significance.

Findings and Conclusions:

The results of the present study extend upon previous findings in which dynamic warm up routines have improved vertical jump, power, and flexibility. The results suggest that approximately 3 minutes and 6 minutes of a dynamic warm-up following a five minute light aerobic jog may increase VJ height, lower body power (peak & average power), and hamstring flexibility, while having a minimal effect on balance and no effect on hip flexor flexibility. Furthermore, there is no difference between 3 and 6 minutes of a dynamic warm up routine, thus only 3 minutes is needed to improve human performance.


ADVISER'S APPROVAL: Dr. Doug B. Smith