

SHORT-TERM TRAINING EFFECTS OF DYNAMIC WARM UP  
VOLUME ON SPEED, POWER, AND AGILITY

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**Title**

Short-Term Training Effects of Dynamic

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## ABSTRACT

Senn, Daniel LeRoy, M.S., Department of Health, Nutrition, and Exercise Sciences, College of Human Development and Education, North Dakota State University, April 2011. Short-Term Training Effects of Dynamic Warm Up Volume on Speed, Power, and Agility. Major Professor: Dr. Donna Terbizan.

This study examined the short-term training effects of two volumes of a dynamic warm up performed 4 days per week over a 3 ½-week period. A total of 25 Division III wrestlers volunteered for the study. Three participants either dropped out or were unable to attend post-testing, resulting in 22 total participants completing the study. Groups were divided into control, low volume, and high volume groups. All participants completed pre and post-study performance tests including the standing long jump, proagility, start-stop-cut, and 30-meter sprint. The low and high volume training groups each performed the same dynamic warm up prior to each pre-season captain's practice. The control group did not participate in an organized warm up. The low volume group performed one set of each warm up exercise, and the high volume group performing two sets of each warm up exercise. Data analysis indicated significant increases in performance for the standing long jump ( $p = .011$ ) and start-stop-cut ( $p = .000$ ) measures among the entire sample population. However, there was no significant difference between the groups in these measures. No significant results were found either for the sample as a whole or between groups for the proagility and 30-meter measures. The increased performance of all groups, including the control group, fails to provide evidence for the effectiveness of training with either warm up volume. Further research is needed to address limitations of this study to determine effectiveness of various warm up volumes.

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## INTRODUCTION

The warm up is an important component of any training or sport practice program. The function and benefits of a well-designed and consistently performed warm up may result in sustainable training adaptations that enhance athletic performance. The general objectives of a warm up are to increase muscle temperature, increase blood flow, stimulate the nervous system, and prepare the muscles, tendons, and connective tissue for subsequent activity. Achieving these warm-up goals may result in faster contraction and relaxation of muscles, enhance rate of force development (RFD) and reaction time, increase muscle strength and power, decrease viscosity of blood, enhance oxygen utilization, and enhance metabolic reactions (Baechle & Earle, 2008; Bishop, 2003). Although the warm up is often performed for its acute benefits, a well designed comprehensive warm up may have training effects resulting in positive cumulative performance adaptations throughout the training cycle (Chappell & Limpisvasti, 2008; Herman & Smith, 2008; Mandelbaum, et al., 2005). However, the importance of the warm up is often overlooked or neglected. A warm up that is poorly designed, neglected, or executed improperly may subsequently result in performance detriments, time wasted, or possibly contribute to injury.

It has been suggested that a warm up performed prior to each practice will have a cumulative training effect and may serve as a conditioning tool (Gambetta, 2007). Gambetta suggested that training effects from a warm up may be especially beneficial for younger athletes due to their learning stage and their large potential for skill improvement. However, these benefits may also have potential to be extended to more mature athletes. In fact, research has documented the short and long-term training effects of warm ups that are designed with appropriate activities and executed properly on desired neuromuscular

performance characteristics (Chappell & Limpisvasti, 2008; Mandelbaum, et al., 2005).

Designing appropriate warm up activities for desired training adaptations provides a proper foundation for the training or practice program, in addition to providing the proper neuromuscular stimulus for subsequent workout or practice activities. Many research studies have provided substantial evidence that in acute settings, a dynamic warm up (DWU) better prepares for, and proves beneficial to, subsequent power and speed performance when compared to a static-stretch or no warm up (e.g., Faigenbaum, Bellucci, Bernieri, Bakker, & Hoorens, 2005; Fletcher & Anness, 2007; Little & Williams, 2006; McMillian, Moore, Hatler, & Taylor, 2006). Research has also supported the performance-enhancing benefits of long-term comprehensive sport conditioning and neuromuscular training programs (Myer, Ford, Palumbo, & Hewett, 2005). These neural training adaptations, such as; enhanced motor coordination patterns, feed forward, and feedback mechanisms, directly influence athletic performance in acute and long-term settings (Ross, Leveritt, & Riek, 2001). To provide the proper stimulus for desired neural adaptations, it is critically important to ensure the athletes are performing the appropriate activities with the proper intent and execution (Young & Bilby, 1993). Based on the above mentioned research findings and training suggestions, there appear to be promising opportunities to enhance the efficacy of a warm up routine in terms of long-term performance benefits accumulated by consistent proper execution of appropriate exercises.

When designing an appropriate warm up, the rule of training specificity states the importance of selecting activities with movement characteristics specific to the selected sport (Brooks, Fahey, & Baldwin, 2005). Success in many sports requires a high degree of strength, speed, power, agility, and dynamic balance and joint stability. These traits

influence the athlete's capacity to perform critical sport skills. With these considerations in mind, a successful warm up routine may be designed to fit the specific preparatory needs of the sport.

Although properly designed and executed warm up routines have resulted in positive performance adaptations, little has been done to evaluate the efficacy of warm up volume in regards to short-term training effects (Herman & Smith, 2008). Evaluating the efficacy of different volumes may provide suggestions for appropriate warm up volume and time allocation that produce performance adaptations at an acceptable cost benefit ratio. Therefore, the purpose of this study was to evaluate the short-term training effects of warm up volume variation. A DWU was designed with training elements focused on developing desired performance traits and movement performance to enhance quickness, agility, speed, and power. By assigning two different warm up volumes and comparing the changes in measured performance tests, evidence was provided on the effectiveness of the DWU protocol and the associated effects of volume.

#### Statement of Problem

Coaches are faced with the task of efficiently utilizing practice time throughout the season to safely and effectively prepare their athletes for optimal skill and physical performance. Practice time in college athletics is often a limited commodity, especially under Division III NCAA rules. A DWU provides an opportunity to efficiently utilize practice time to develop these skills and physical attributes. However, due to the lack of evidence, it is unclear as to what the most effective volume of warm up is to prescribe, and what the potential is for performance adaptations. Therefore the problem of prescribing warm up activities and assigning a respective volume to these activities was investigated.

### Purpose of Study

The purpose of this study was to compare the short-term training effects of two different DWU volumes on speed, power, and agility measures.

### Research Question

Will there be a statistically significant difference at the end of a 3 ½ -week period between low volume and high volume DWU groups in measured speed, power, and agility performance?

### Focus of Study

The focus of this study was to determine the effectiveness of volume of DWU to elicit short-term training adaptations to neuromuscular coordination characteristics influencing the performance of speed, power, and agility measures in Division III wrestlers. The low volume treatment consisted of one set of each warm up exercise, and the high volume treatment consisted of two sets of each exercise. The results of this study provided evidence of the effectiveness of a dynamic warm up implemented as a movement training tool, and the efficacy of two differing of warm up volumes to elicit short-term training adaptations. These results provide coaches with additional insight for determining an appropriate volume of warm up exercises to employ, and the value of allocating additional time to extend warm up activities.

### Study Limitations

1. The study was delimited to Division III wrestlers participating at a private college.
2. Certain volunteering participants were restricted from participating in the treatment groups due to class schedule. These participants were allowed to form a control group to strengthen the research design.

3. The co-investigator was limited to attending and supervising only half of the scheduled training sessions. Team captains participating in the study assumed responsibility of supervising all remaining scheduled sessions.
4. The length of the treatment period was limited to only 3 ½ weeks, over which 14 scheduled sessions took place.
5. Throughout the study a number of participants were absent from scheduled sessions. These participants were responsible to make up these sessions on their own as able to.
6. The strength of study design was also limited by the lack of control over external factors such as resistance training and attendance to captains' practices. Many participants were involved in weight training and captains' practice, but attendance and adherence were not required.
7. The study design was also limited by the timing of the study period. The study period extended through the first week of regular season practice, with testing taking place following this full week of practice.
8. The number of participants in this study was limited to a total of 22, which were divided into groups of seven, eight, and seven in the high volume, low volume, and control groups respectively.

#### Definition of Terms

Dynamic (referring to a dynamic exercise, stretch, or activity)- an active movement where limbs are moved through a joint range of motion as a result of active muscle forces and influenced by external forces such as gravity, ground reaction forces, velocity, etc (Brooks et. al., 2005).

Motor Coordination- the function of the nervous system organizing the activation of muscles to achieve a movement or action goal (Magill, 2004).

Motor Coordination Patterns- trainable performance parameters under direct neural influences, such as reflexes and stored motor programs, which control body movements. These performance parameters include the speed, magnitude, and duration of nervous output that subsequently influence muscular force and power output, and the sequential neural activation patterns of muscular control that influence technical skill performance (Magill, 2004).

Movement- behavioral characteristics of body and limb actions (Magill, 2004).

Muscle Stiffness- an influencing factor of stretch-shortening cycle performance, a variable measure of muscle elasticity dependant on muscle activation and forces exerted. As muscle tension increases, muscle stiffness increases, and therefore increases resistance to stretch under load and acts like a stiff spring during high intensity ballistic movements (Zatsiorsky & Kraemer, 2006).

Neuromuscular- refers to the interaction between the nervous system and the musculoskeletal system to act as an organized system to produce movement (Brooks et. al., 2005).

Neuromuscular Control- refers to any aspect surrounding nervous system control over muscle activation and the factors contributing to task performance (Riemann & Lephart, 2002a).

Neuromuscular Training- techniques designed to alter motor coordination patterns by influencing neural outputs (central nervous control and proprioceptive mechanisms), which subsequently control muscle contractions in order to reduce injury and enhance sport

performance by addressing biomechanical weaknesses and imbalances, and performance characteristics respectively (Myer et. al., 2005).

Plyometrics- a quick, powerful movement using a pre-stretch or counter movement that involves the stretch-shortening cycle. The purpose of which is to increase the power of subsequent movements by using both natural elastic components of the musculotendinous unit and the stretch reflex (Baechle & Earle, 2008).

Proprioception- afferent information from internal peripheral areas of the body that contribute to reflex mechanisms that influence postural control, joint stability, and conscious sensations (Riemann & Lephart, 2002b).

Rate of force development (RFD)- the development of force over a period of time. A high rate of force development is associated with high explosive strength. The goal of enhancing rate of force development is maximizing force produced and movement velocity (Zatsiorsky & Kraemer, 2006).

Static-stretch- refers to a passive movement throughout a joint range of motion in which a limb is passively moved through a joint range of motion to a point where muscular and joint resistance restricts further motion, and then held in that static stretched position for a certain duration in attempt to increase joint range of motion (Baechle & Earle, 2008).

Stretch-shortening Cycle (SSC)- a mechanism that utilizes the stored elastic energy within the musculotendinous unit accumulated during an eccentric loading phase, stimulating a reflex action, and coupling this reflex with the concentric phase to facilitate maximal force production (Zatsiorsky & Kraemer, 2006).

## REVIEW OF LITERATURE

Warm ups are an integral portion of a training or practice session. There are both physiological and psychological benefits that prepare the athlete for the stresses and exercise intensity of each session. Although there is substantial support for the preferential use of a DWU prior to power and speed related activities (e.g., Fletcher & Anness, 2007; Sim, Dawson, Guelfi, Wallman, & Young, 2009), there is little research evaluating the effects of different warm up volumes on power performance. In addition, there are numerous research studies evaluating the acute effects on performance (e.g., Fletcher & Anness, 2007; Holt & Lambourne, 2008; McMillian et. al, 2006) however, very little evaluating the short-term training effects of a consistently performed DWU (Herman & Smith, 2008). Therefore, the purpose of this study was to examine the short-term training effects of two different DWU volumes on speed, power, and agility.

There are a number of general objectives of performing a warm up prior to a training session. However, possibly the most important function of appropriately stimulating the nervous system is most often neglected (Brooks et. al., 2005; Gambetta, 2007). The general functions of a warm up include increasing the temperature of active tissue resulting in an increase in metabolic rate and speed of muscle contraction, increasing cardiac output, capillary dilation in active muscle tissue to increase blood flow and oxygen delivery, assisting in regulation of blood pressure, fine tuning motor skills, and psychologically preparing the athlete for subsequent activity or competition (Brooks et al., 2005; McArdle, Katch, & Katch, 2006). These functions are important and should not be overlooked or excluded. However, characteristics of muscle movement largely determine athletic performances such as speed, power, and agility.



Since muscle contractions and subsequent joint and limb movements are under direct control of the nervous system, it is critically important not to overlook the neural preparation and training functions of a warm up. Much of the research evaluating the acute effects of warm ups utilize performance tests that include measures of power, speed, and agility (e.g., Little & Williams, 2006; McMillian et al., 2006). There appears to be a significant neural influence on high power output activities (Ross et. al., 2001). The differences found in power-related performance between static stretching and dynamic activity warm ups provide evidence of the neural enhancing effects of a DWU and the possibly neural depressing effects of a static stretch warm up (Fletcher & Anness, 2007; Holt & Lambourne, 2008; Hough, Ross, & Howatson, 2009).

#### Types of Warm Ups

Just as there are several types of sport training and conditioning programs, there are also several types of warm ups, each having an influence on subsequent performance. A general preliminary warm up exercise routine may be described as a warm up that accomplishes tasks such as increasing core and muscle tissue temperature and increasing heart rate and cardiac output (Brooks et al., 2005). A general warm up does not specifically attempt to mimic movement characteristics of the subsequent training or practice session. Activity may include an aerobic activity such as jogging or cycling followed by light stretching.

A sport specific warm up may follow a general warm up and includes activities selected to specifically prepare the athlete for the stress and intensity of the subsequent activity. Warm up activities would include movement and neural patterns and characteristics similar to those required in the training session or skill practice (Gambetta,

2007). Examples of movement patterns would include quick and powerful hip flexion and hip extension for sprint performance or throwing drills targeted for throwing athletes. Movement characteristics for power athletes such as sprinters and jumpers, or football, soccer, and baseball players would emphasize warm up exercises that utilize plyometric type movements such as skips, bounds, and jumps to train the stretch-shortening cycle (SSC) component of critical movement skills. Within the general and sport specific warm ups are different modes of warm ups, most notably static stretch and active dynamic strategies, each of which are performed based on habits, beliefs, philosophies, and goals.

A static stretch warm up has traditionally consisted of a light continuous aerobic activity such as a 5-minute jog, followed by a period of static stretching believed to enhance performance and reduce injury (Smith, 1994; Woods, Bishop, & Jones, 2007). A static-stretch warm up may also be known as a more traditional warm up due to its previous extensive use. Static stretching involves different modes of passive and/or resisted movements designed to increase the elasticity of musculotendinous units resulting in an increase in passive joint angle range of motion referred to as passive flexibility. However, there is a growing consensus that suggests there is a lack of evidence to support the injury preventive benefits of static stretching prior to exercise (Faigenbaum & McFarland, 2007; Knudson, 1999; Thacker, Gilchrist, Stroup, & Kimsey, 2004; Young & Behm, 2002), and an overwhelming consensus that static stretching inhibits acute performance particularly in maximal power events (Faigenbaum & McFarland, 2007; Faigenbaum et al., 2005; Knudson, 1999; McMillian et al., 2006). The consensus now favors the use of dynamic warm ups.

While a static-stretch warm up incorporates passive mobility throughout the joint range of motion, a DWU, also known as a dynamic stretch warm up, incorporates active mobility and movement drills that emphasize the neuromuscular patterns specific to that sport (Beachle & Earle, 2008). A DWU incorporates sport-specific elements in terms of direction of force production, along with other aspects such as rate of force development. For example, the sprints in track and field require rapid, powerful hip flexion and extension. Therefore included in the DWU would be exercises that emphasize execution of rapid hip flexion and extension. In addition, the athlete would be provided verbal cues that direct the athlete to properly execute these movements throughout the exercise.

#### Performance Effects of Warm Ups

Research has documented both short and long-term training effects of a DWU to enhance neuromuscular performance and coordination, resulting in increased athletic performance and decreased injury occurrence (Herman & Smith, 2008; Mandelbaum et al., 2005). These warm ups were dynamic in nature, consisting of various intermittent exercises that progressively increase in intensity. Exercises included form runs, plyometrics, agility drills, and strengthening exercises. Research continues to support the efficacy of DWU exercise to replace the more static exercises that have been prevalently used in the past.

There is a considerable amount of conflicting research and claims concerning static versus dynamic warm ups. Previously, research promoted static stretching as a means of improving flexibility, reducing injury, enhancing athletic performance, alleviating muscle soreness, and rehabilitating injury (Smith, 1994). However, there is mounting evidence refuting the claims of injury prevention (Faigenbaum & McFarland, 2007; Knudson, 1999; Thacker et. al., 2004) and exposing the detrimental effects of static-stretch warm ups on

athletic performance and conversely supporting the benefits of a DWU (Faigenbaum et. al., 2005; Faigenbaum & McFarland, 2007; Fletcher & Anness, 2007; Herman & Smith, 2008; Holt & Lambourne, 2008; Knudson, 1999; McMillian et al., 2006; Needham, Morse, & Degens, 2009; Sim et. al., 2009; Young & Behm, 2002). Much of this research has focused on acute performance effects of static-stretch versus dynamic warm ups. This research has shown the detrimental effects of static stretching and conversely the performance enhancing effects of a dynamic warm up. The above research noted possible mechanisms thought to be responsible for reduced performance following static stretching including a negative influence on neural mechanisms and reduced musculotendinous stiffness. Conversely, possible mechanisms suggested to result from a DWU include enhanced neural activation, positive changes in the force-velocity relationship, increased metabolic activity, and maximizing active range of motion (Bishop, 2003; Faigenbaum et al., 2005; Faigenbaum & McFarland, 2007).

A number of studies have compared the acute effects on power-related performance between warm up variations consisting of static stretching only, combinations of static and dynamic activities, dynamic and high resistance exercises, and dynamic activities only. An extensive report of these studies is beyond the scope of this study. However, to provide some examples, Faigenbaum et. al. (2005), Fletcher and Anness (2007), Holt and Lambourne (2008), Needham, Morse, and Degens (2009), Sim et. al. (2009), and Thompsen, Kackley, Palumbo, and Faigenbaum (2007) have all demonstrated detriments in power performance following warm ups consisting of static stretching, and subsequently advocated the exclusive use of dynamic activities due to the resulting enhancement in the

following power-related performance measures. The results of these studies allow generalizations to be made to both males and females ranging from youth to college ages.

McMillian et al. (2006) found similar results comparing the acute effects of static-stretch and dynamic warm ups in military cadets. Of significance was a follow up to this study by Herman and Smith (2008). Herman and Smith duplicated the warm up protocols but extended the use of the warm up protocols over a 4-week period during pre-season to examine short-term, sustained training adaptations resulting from these treatments. Two groups of college wrestlers, one group assigned to the static stretch and the other to the DWU, performed these respective warm up protocols prior to pre-season practices. Wrestlers in the DWU intervention showed improvements in several measures of power, agility, endurance, strength, and anaerobic capacity. In contrast, the static-stretch group showed no improvements in strength, power, agility, and anaerobic capacity, as well as decrements in endurance and muscular endurance measures. This study is one of very few that examine sustained performance adaptations of a short-term DWU program, and subsequently exhibit promising objective evidence of the training and conditioning benefits of implementing an exclusively DWU. Additionally, the study appears to show that the performance effects of a DWU extend beyond that of an acute setting, thus supporting the efficacy of dynamic warm up activities to produce sustained training adaptations in the neuromuscular performance mechanisms.

#### Neuromuscular Training

Neuromuscular training is a strategy of training, mainly targeted to female athletes, to correct neuromuscular deficits to reduce the risk and occurrence of lower body injuries (Chappell & Limpisvasti, 2008; Fischer, 2006; Hewett, Myer, & Ford, 2001; Mandelbaum

et al., 2005; Myer et al., 2005). The primary training goal is to program the coordination patterns of the neuromuscular system to perform athletic maneuvers, such as jumping, landing, changing direction, in a powerful, efficient, and safe manner (Hewett et al.). The targeted neuromuscular functions include reprogramming motor coordination patterns to increase speed and magnitude of muscle contractions to enhance functional joint stability during sport maneuvers, and challenging sensorimotor feedback and feed forward mechanisms to enhance planning and reaction to environmental variables.

Neuromuscular training programs have been designed for use in the context of a warm up for sport practice (Grandstrand, Pfeiffer, Sabick, DeBeliso, & Shea, 2006; Mandelbaum et al., 2005) and as a comprehensive off-season sport conditioning program (Chappell & Limpisvasti, 2008; Paterno, Myer, Ford, & Hewett, 2004; Myer et al., 2005). A neuromuscular training program often incorporates dynamic mobility, passive stretching, speed and agility drills, plyometrics, and strength, core stability, and balance exercises. Program design takes a holistic approach based on sport movement specificity, neuromuscular patterning in accordance to performance goals, and program execution is advised to be performed under close supervision and feedback by a qualified instructor (Hewett et al., 2001).

Neuromuscular training is a term that has been mainly associated with an area of research within the sports medicine community, and is often used to describe a novel training concept. However, the design elements and mode of execution of neuromuscular training programs are based on the same foundational elements as any other well designed comprehensive sport conditioning program. The sports medicine community has used the neuromuscular training term to identify a scope of research mainly aimed to address the

problem of non-contact lower body injuries in the female athlete. However, the information provided by neuromuscular training research has been very valuable in strength and conditioning research as well. Neuromuscular training research provides strength and conditioning researchers with evidence that acute performance enhancements of a DWU may be extended to sustainable training adaptations over short-term training periods. Although the type of warm up used by Herman and Smith (2008) and several other previously noted studies were not labeled as neuromuscular training programs, the principal guidelines used to design these programs and the subsequent training goals are similar to those used in research using programs labeled as neuromuscular training programs. Therefore, results of neuromuscular training studies provide evidence of the efficacy of purposefully designed warm up protocols to elicit short-term sustainable training adaptations that improve performance measures.

Hewett et al. (2001), Irmischer et al. (2004), Myer et al. (2005), Myer, Paterno, Ford, and Hewett (2008), and Paterno et al. (2004) provided similar examples of neuromuscular training protocols that have been successful in reducing injury and causing sustained training adaptations in neuromuscular coordination resulting in changes in movement mechanisms and increases in lower body measures of power and stability. These programs were designed as comprehensive off-season programs consisting of various strength, balance and stability, plyometric, and dynamic movement exercises. Similarly designed abbreviated protocols have also been implemented as pre-practice warm ups with similar training adaptations.

Grandstrand et al. (2006) implemented an 8-week warm up program performed two times per week to evaluate the effects on landing mechanics. They found no statistically

significant improvements within the treatment groups. However, there were improvements made within the groups that the researchers felt were of clinical significance in terms of reducing the risk of injury. In this study the treatment occurred only two times per week and was conducted with youth female soccer players.

Chappell and Limpisvasti (2008) also implemented a pre-practice neuromuscular training warm up. The 10-15 minute warm up was performed six times per week over a 6-week period. Changes in lower body mechanics during jumping and landing tasks were mixed. However, there were significant improvements in vertical jump performance and in a timed single-leg hopping task. Chappell and Limpisvasti suggested future studies should further investigate the efficacy of program length. This study showed that high-level college aged female athletes are capable of accumulating sustainable beneficial adaptations from a well developed and consistently performed neuromuscular focused warm up.

Mandelbaum et. al. (2005) implemented a 15-20 minute, three times per week, neuromuscular training warm up to evaluate the occurrence of lower body injury over two seasons. The study was conducted in participation with a female youth soccer league. Coaches participating in the treatment group were sent an instructional video describing the protocol and educating them on proper instruction. Fifty-two of the 95 teams, and 45 of the 112 teams performed the warm up in the first and second season respectively. The occurrence of anterior cruciate ligament injury substantially decreased in the treatment groups over both seasons when compared to the control groups. Although no pre or post-performance measures were tested, the significant reduction in injury occurrence in the treatment groups suggest that there is a reasonable inference that the warm up treatment



lead to neuromuscular adaptations that made the athletes less vulnerable to incurring injury (Mandelbaum et. al.).

### Mechanisms of Desired Performance

Many popular competitive sports require a certain degree of strength, power, speed, and mobility for optimal performance and success. Several factors of neuromuscular performance and physical musculoskeletal characteristics determine the strength, power, agility, and speed capacities of athletes. These characteristics can be improved through appropriate training (e.g., Chappell & Limpisvasti, 2008; Herman & Smith, 2008; Mihalik, Libby, Battaglini, & McMurray, 2008; Mujika, Santisteban, & Castagna, 2009; Murray, et al., 2007)

Wrestling is a sport where competitors are matched by body weight to equalize competitive advantage. Therefore, given two wrestlers with equal weight and technical skill, it would be reasonable to suggest that the wrestler with greater strength, power capacity per pound, and greater mobility and endurance will have a distinct advantage over their opponent. With opponents matched by weight class, wrestlers rely on technical skill, strategy, and athletic performance to defeat their opponents. Flawless skill execution and timing can greatly influence the allocation of points or the outcome of a match. A match requires a great amount of muscular endurance, and also requires an opportunistic application of quickness and power for successful execution of technical moves to gain advantage over an opponent. Off-season, pre-season, and in-season performance training is a common practice to develop and maintain performance attributes critical to success during the competitive season (Baechle & Earle, 2008).

The principle of training specificity plays a crucial role in developing the factors that improve strength, power, agility and speed (Zatsiorsky & Kraemer, 2006). Therefore, exercises must emphasize and develop skill characteristics including limb velocity, rate of force development, rapid SSC mechanisms, and behavioral specific movement parameters that resemble key movement skills of the sport. The task-specific training goals for this study significantly rely on maximizing force production over a minimal period of time. This goal is achieved by enhancing factors such as rate of force development and the efficiency of the SSC component.

The rate of force development (RFD) is a power-related variable that is important in skills such as sprinting, jumping, and throwing (Brooks et al., 2005; Zatsiorsky & Kraemer, 2006). Training this component requires speed loading, moving a resistance as rapidly as possible (Brooks et al.). Training exercises include explosive movements such as squat jumps, medicine ball throws, and acceleration/deceleration drills.

Plyometric loading is useful for training the neural and elastic components of strength (Brooks et al., 2005). Plyometrics involve a loading pattern that utilizes the SSC mechanism. The SSC involves a sudden eccentric stress and subsequent muscle stretch, followed by a rapid concentric contraction that utilizes the stored elastic energy before it is dissipated as heat. Efficient use of the elastic energy increases force and power output and reduced energy expenditure (Zatsiorsky & Kreamer, 2006). Efficient coupling of the eccentric-concentric actions requires a certain degree of musculotendinous stiffness and neural reflex (Zatsiorsky & Kraemer). Stiffness has been established as a beneficial factor influencing athletic performance (Butler, Crowell, & McClay-Davis, 2003; Wilson & Flanagan, 2008). Stiffness contributes to the optimal utilization of the SSC; additionally,

the amount of stiffness required for an activity increases as intensity increases (Butler et al.). Stiffness has been established as a beneficial performance factor with its positive contribution to the SSC, and its correlation with force output, velocity, running economy, and decreased ground contact times (Wilson & Flanagan).

Based on a review of literature, Wilson and Flanagan (2008) evaluated the research to develop benefits of stiffness and training suggestions to enhance stiffness.

Neuromuscular training programs and plyometrics were suggested to improve muscle preactivation, stiffness, muscle activation latency, and efficiency of the SSC. Fatigue and stretching appeared to negatively influence stiffness. In addition, it was suggested that training stimulus is reduced when power-related activities are performed in a fatigued state due to the improper exercise execution. Therefore, power-related activities and skilled movements should be performed earlier in the training session in a non-fatigued state to optimize training adaptations through proper exercise execution. Butler et al. (2003) also suggested through a review of literature that stiffness can be modified in response to verbal cues. Athletes alter their mechanics when directed to minimize ground contact times during ballistic movements and are also able to soften landings from jumps to reinforce proper form. Stiffness is also influenced by neural reflex mechanisms by activating muscle spindle activity in response to sudden high stretch loads. Plyometric training is also suggested to enhance this reflex response (Brooks et al., 2005).

Muscular contraction and subsequent joint and limb movement is under direct control of the nervous system. Therefore, force production and movement coordination is also controlled by nervous output. The nervous system varies force production by three factors: motor unit recruitment, the rate of neural signals, and the synchronization of motor

units activated (Zatsiorsky & Kraemer, 2006). Recruitment, also referred to as the size principle of motor unit activation, is the graduated activation of motor units of increasing size and number in response to an increase in force required for the activity. Rate coding, or the discharge frequency of motor signals, also influence the gradation of muscle force. As neural firing rates increase, force and power production also increase. Synchronization, or simultaneous activation of multiple motor units, also has a positive influence on force and power production (Ross et. al., 2001).

The ability to exert maximal force for a given activity is a trained skill (Zatsiorsky & Kraemer, 2006). The proper training stimulus results in neural adaptations that allow the athlete to enhance coordination of neuromuscular activation. This strategy, requiring full effort execution of movements, is referred to as the dynamic effort method (Zatsiorsky & Kraemer). The dynamic effort method incorporates a training stimulus that applies a submaximal resistance load, and movements are attempted to be performed at the highest attainable speed.

The training strategy applied in the current study is similar to that of the dynamic effort method. Training stimulus was provided by ground reaction forces and body weight loading during dynamic movements, with force production maximized with rapidity of movements. The dynamic effort method is designed to increase the RFD and explosive strength capacities, not to increase maximal strength (Zatsiorsky & Kraemer).

Young and Bilby (1993) also suggested the significance of training motor unit recruitment patterns and motor unit firing frequency with conscious efforts to produce adaptations in RFD. Subjects attempting to produce fast concentric contractions during a moderate load half-squat exercise had much higher percentage gains in RFD compared to

subjects performing slow contractions. They suggested that gains in maximum RFD are influenced by neural adaptations and may be substantial when training focuses on voluntary efforts to produce maximum speed of muscle contractions during movements of resistance exercises.

Agility characteristics encompass the ability to perform multidirectional movements and changes of direction. Agility performance is highly reliant on speed and power production. As mentioned above, maximal force production is a trained skill. In addition to this, agility activities are learned skills in themselves because of the movement technique requirements. Agility skills are learned and programmed in the motor cortex of the brain and activated through the nervous system to control the coordination patterns of motor unit recruitment in respect to time, space, frequency, and amplitude (Brooks et al., 2005). Although agility performance benefits from speed-strength and power training, transfer to agility skills is more likely enhanced by making training exercises more specific to movement parameters specific to the agility requirements of the sport. However, change of direction performance is also highly dependant on trained vertical RFD capacity.

Barnes et al., (2007) suggested that change of direction performance during an agility task may be limited to a greater extent by vertical forces as opposed to horizontal forces. Using a force plate positioned at the point of direction change during an agility task, results showed that the majority of total force produced during the change of direction task was vertical. Although these results do not undermine the importance of movement technique and horizontal force development during an agility task, the results do reinforce the significant contribution of vertical force development during a horizontal task.

Therefore, training for agility performance should not focus solely on horizontal movement and should involve enhancing the vertical force development components.

To develop speed-strength, athletes specifically overload the neuromuscular system with plyometric and speed building exercises to stimulate and increase in power and speed of muscle contraction (Brooks et al., 2005). Developing maximal power requires coordination of neural activation, storage, and release of muscle elastic energy and contraction of muscle (Brooks et al.).

Several studies have attempted to determine the type of training that best improves athletic performance in a variety of measures such as speed, strength, power, and agility. Many of these studies conclude that training programs involving combinations of load and velocity elements provide optimal results. Lyttle, Wilson, and Ostrowski (1996) concluded that a combination of heavy weights and plyometric training produced superior performance in SSC movements compared to a high power program involving only weighted squat jumps and bench press throws. Harris, Stone, O'Bryant, Proulx, and Johnson (2000) also found optimal results in strength, power, and speed with the use of a combination program.

Performance measures of speed, power, and agility require high velocity movements. According to McBride, Triplett-McBride, Davie, and Newton (2002), performance increases in these high velocity measures may most benefit from the high velocity movements performed in the treatment warm up. McBride et al. reinforced the training effect of the load-velocity relationship. Results showed that training loads and velocity produced velocity-specific increases in muscle activation. Both light and heavy-load resistance groups performed exercises with the intent of producing maximum velocity

movements. Both groups made significant improvements in performance measures. However, the light-load, high-velocity group showed greater velocity increases in muscle activation.

### Relevant Design and Implementation Suggestions

When learning a new skill or training the neuromuscular system for certain movement performance characteristics, it is critically important the athlete stay on-task with training objectives. This is achieved by consistent proper execution of exercises in accordance to their training purpose. According to Hewett et al. (2001), proper instruction of a neuromuscular program requires immediate, consistent, and motivational feedback and direction throughout the training session. This includes cueing the athletes to keep ground contact times minimal, maintain proper posture and movement mechanics, and perform soft landings when applicable.

Based on research findings and suggestions made by researchers and authors noted previously, there are a number of considerations to follow when designing and implementing a warm up for developing desired performance characteristics. The performance goals of this warm up included enhancing RFD, SSC function, neural coordination and firing rates, and enhancing both horizontal and vertical ground force production. Training these basic physiological components have been suggested to provide a specific means of training for and transferring to desired athletic performance in the form of increased strength, power, speed, and agility.

In the current study, warm up exercises were designed to emphasize dynamic loads and movements against gravity and accentuate ground reaction forces. Exercises were executed in a way to produce movements at high velocity and with minimal ground contact

times. Athletes were instructed to execute movements by attempting maximum vertical height and horizontal distance when applicable. This means of training, consistent with the dynamic effort method, focuses on the use and development of SSC components that enhance musculotendinous stiffness and reflex response, and enhance neural stimulation by increasing firing rates and motor unit recruitment patterns (Zatsiorsky & Kraemer, 2006).

The warm up protocol in the current study followed a progression of low to high intensity. In addition to focusing on development of speed, power, and agility; metabolic demands of the sport of wrestling were considered. Wrestling requires muscular endurance and the ability to perform quick, powerful movements under muscular fatigue. Participants were encouraged to maintain proper execution as fatigue accrued. As fatigue accrued and exercise execution diminished to a point of inhibiting proper exercise execution, participants were encouraged to lengthen periods of active rest between exercises. This added active rest allowed participants to adequately recover; enabling them to maintain focus on proper exercise execution throughout the duration of the warm up.



## METHODS

The purpose of this study was to compare the short-term training effects of two different DWU volumes on speed, power, and agility. To accomplish this, a dynamic neuromuscular training warm up was designed to train the neuromuscular system for better speed, power, and agility based on guidelines for improving critical performance aspects. Participants were divided into three groups; a control, low volume, and high volume. Each study participant was tested prior to and following the study with tests measuring power, agility, and speed. Both high volume and low volume training groups performed the same neuromuscular training warm up, with the low volume group performing one set of each exercise and the high volume group performing two sets of each exercise. Following post-testing, data from pre-test scores were used to identify any significant group differences prior to the study treatment. Pre-test and post-test performance scores were used to analyze and determine group differences for change in test performance within and among groups.

### Population Sample and Sampling Procedures

Participants in this study included male college athletes participating in Division III wrestling. Permission to invite the wrestlers to participate was obtained from the head coach through a letter of permission (Appendix A). Permission to utilize indoor facilities for testing and study treatments was obtained by letter of permission from the athletic director (Appendix B). Study approval was obtained from the Institutional Review Board of both the primary institution (Appendix C) and the institution where the study was conducted (Appendix D). A letter explaining the study and inviting participation was then sent to the head coach and subsequently sent to all wrestlers. There were approximately 30 wrestlers participating in pre-season captains' practices at the time of solicitation. The co-

investigator of the study met with the wrestling team before one of their afternoon captains' practices. The purpose and design of the study was explained in detail, and informed consent obtained (Appendix E) from those wishing to participate. Participants were also required to complete a Physical Activity Readiness Questionnaire (PAR-Q) (Canadian Society for Exercise Physiology, 2002) to identify and exclude wrestlers with any injury or condition that may restrict performance and limit exercise activities. The PAR-Q is displayed in Appendix F.

Division III athletics have strict limitations on requiring mandatory attendance to team activities outside of the regular season. Therefore, participants had no mandatory or commonly shared schedule. In addition, at the time of the study, the wrestlers were not following any kind of organized dynamic warm up prior to off-season activities. Throughout the pre-season, many of the wrestlers follow a self-guided resistance training program and participate in captains' practices. Initially, the intent of the study design was to implement the treatment warm ups at the beginning of each resistance training session. With the inability to reach a consensus and commit to certain resistance training session times, participants agreed that the treatment schedule would be more easily accommodated if performed prior to captains' practices in the afternoons.

Group assignments for the study were then narrowed down to treatment and control groups. Those who were unable to accommodate the afternoon treatment schedule were placed in the control group. These participants volunteered for the study, but agreed to form a control group since their class schedule restricted them from participating in the pre-practice treatment schedule. Therefore, the control group was self-selected.

Since body type was expected to influence test scores, exercise performance, and subsequently group statistics, random assignment to test groups were made by weight class to distribute body types between the two treatment groups. All remaining participants not included in the control group were listed by weight class. Participants were instructed to list their weight class based on their current weight. Subsequently, participants in each weight class were randomly assigned to either the high or low volume group. Participants were grouped in their respective weight class. Weight classes were then organized in an order of lightest to heaviest. Starting with the lightest weight group, participants were randomly divided between two groups. This procedure continued through the entire list of weight classes until all participants were assigned to a group. This method of random assignment was similar to the method used by Herman and Smith (2008) to evenly distribute body types between the two treatment groups. Distribution of participants among groups is listed by weight class and presented in Table 1.

Since participants in the control group were unable to accommodate the treatment schedule due to class schedule conflicts, year in school information was gathered to determine if participants' year in school may have been a reason for class schedule conflict. The control group consisted of two freshmen, two sophomores, and three juniors. The low volume group consisted of three freshmen, one sophomore, two juniors, and two seniors. The high volume group consisted of four freshmen, one sophomore, and two seniors. With exception of the absence of seniors from the control group, participants' year in school did not appear to influence ability to accommodate the treatment schedule.

Table 1. Group Participants by Weight Class

Weight Class	High Vol.	Low Vol.	Control
125 lb.	0	0	3
133 lb.	1	1	0
141 lb.	2	2	1
149 lb.	1	1	1
157 lb.	1	2	0
165 lb.	0	1	1
174 lb.	1	0	0
197 lb.	1	0	1
Heavyweight	0	1	0
Total	7	8	7

### Testing

The goal in selecting the tests was to use basic field tests that measured the selected performance traits, and could easily be understood and executed by study participants. Training effects were assessed by measuring test performance immediately prior to and following the study treatment period. All subjects were assessed for maximal power, agility, and speed using four field tests.

Maximal power was measured using a standing long jump (SLJ) protocol (Baechle & Earle, 2008). The SLJ has been a widely used field test to assess lower body maximal power and has been accepted as a reliable and valid instrument (Castro-Pinero et. al., 2010);

Kirby, 1991; McGee & Burkett, 2003; Harris et. al., 2000; Markovic, Dizdar, Jukic, and Cardinale, 2004; Mayhew, Bembem, Rohrs, and Bembem, 1994). Harris et. al. has specifically noted a test-retest reliability of  $r \geq 0.90$  in their laboratory. Markovic et. al. investigated the reliability and factorial validity for several vertical and horizontal jumping measures that are used to assess lower body explosive power. The SLJ was found to be a reliable measure with Cronbach's alpha reliability coefficient and intraclass correlation coefficient values of 0.95 and 0.95 respectively. Castro-Pinero et. al. also found the SLJ to have a strong association with various lower body strength tests ( $R^2 = 0.829-0.864$ ). Mayhew also found the SLJ to be a valid measure of a lower body speed/strength component using factorial analysis (0.78).

The proagility test is a commonly used test to assess the ability to stop, start, and change direction in a rapid controlled manner (Baechle & Earle, 2008). Both the SLJ and the proagility are used as part of the National Football League Combine battery of tests, and have been used as a reliable and valid measure of athletic ability (Dupler, Amonette, Coleman, Hoffman, and Wenzel, 2010; Faigenbaum et. al., 2005; Gains, Swedenhjelm, Mayhew, Bird, and Houser, 2010; Harris et. al., 2000; Markovic, Jukic, Milanovic, & Metikos, 2007; McGee & Burkett, 2003). Gains et. al. found the proagility to be a reliable measure with intraclass correlation coefficients between 0.82-0.98 when performed on field turf and natural grass. Dupler et. al. provided evidence of the validity of the proagility to distinguish athletes of differing ability.

The 30-meter sprint test is commonly used as a measure of speed and SSC performance (Harris et. al., 2000; Hennessy, & Kilty, 2001; Young, McDowell, & Scarlett, 2001). Harris et. al. has specifically used the 30-meter test with a consistent reliability of  $r$

$\geq 0.90$ . Green, Blake, and Caulfield (2010) also found the 30-meter to be a reliable measure with an intraclass correlation coefficient of 0.97. Green et. al. also determined the 30-meter to be a valid measure distinguishing athletes of differing ability with an effect size  $> 0.8$ .

The start-stop-cut test measured the ability to start and accelerate quickly, execute high speed stops and backward and forward sprints, and to make a 90-degree cut (Dintiman & Ward, 2003). Although no studies were found that utilized the start-stop-cut test, the test included movement elements found in other agility tests. The start-stop-cut test consists of multiple changes of directions and movement transitions between forward, backward, and lateral movement.

These tests were selected based on the simplicity of administering the tests and the reasonable amount of required time needed to complete the battery of tests. The tests are also simple to execute, have straight-forward goals, and participants were comfortable with how to perform them.

#### Standing Long Jump

The SLJ test was completed on soft indoor gym floor surface. A piece of tape two to three feet long was placed on the floor to serve as a starting line. The measuring tape was then extended perpendicularly from the middle of the starting line to assist in measuring and to provide the athlete with a straight guide for directing a straight jump. The athlete stood with toes just behind the starting line and performed a countermovement by swinging their arms and then jumping forward as far as possible. The athletes were instructed to land on their feet in order for the jump to be scored. The trial was repeated if the athlete failed to land on his feet. The jump distance was measured with a tape measure between the back edge of the starting line and the back edge of the athlete's rear-most heel.

Trials were measured to the nearest centimeter and the best of three trials were used for data analysis (Baechle & Earle, 2008).

### Proagility

The proagility test was performed on the same gym surface as the SLJ. Three parallel lines were marked with tape 5 yards apart. The athlete was instructed to straddle the center line in a preferred stance. They were instructed that time would be started upon their first movement. The athlete then sprinted to an outside line, changed direction by 180 degrees, and then sprinted 10 yards to the opposite line where another 180-degree change of direction was made, and then sprinted 5 yards through the center line again. Athletes were also instructed that hand contact must be made with both outer lines during the change of direction. The trials were measured to the nearest .01 second, and the best of two trials were used for analysis (Baechle & Earle, 2008).

### 30-meter Sprint

The 30-meter sprint test was performed on an indoor track surface. The athletes were instructed to assume a staggered three point stance behind the start line. They were directed that time would be started upon their first movement, and to sprint through the finish line. Trials were recorded to the nearest 0.1 second, and the average of the two times were used for analysis. Athletes were reminded to sprint maximally through the finish line without slowing down prior to the finish line (Baechle & Earle, 2008).

### Start-stop-cut

A 10-yard square was marked off on the gym surface (Figure 1). The athletes were instructed to assume a three-point stance, and time would start upon their first movement. The athletes were then instructed to follow this sequence; sprint forward and execute a stop

at the 10-yard line making sure both feet cross the line, then back-peddle 10 yards to the starting line, then shuffle laterally 10 yards to the opposite corner, then sprint forward 10 yards and then execute a stop and 180-degree turn making sure both feet cross the 10-yard line, then sprint forward 10 yards through the finish line. One trial was performed from both the lower left and lower right corners for a total of two timed trials. Trials were recorded to the nearest 0.1 second with the average of the two times used for analysis (Dintiman & Ward, 2003). Athletes were reminded to sprint maximally through the finish line without slowing down prior to the finish line.

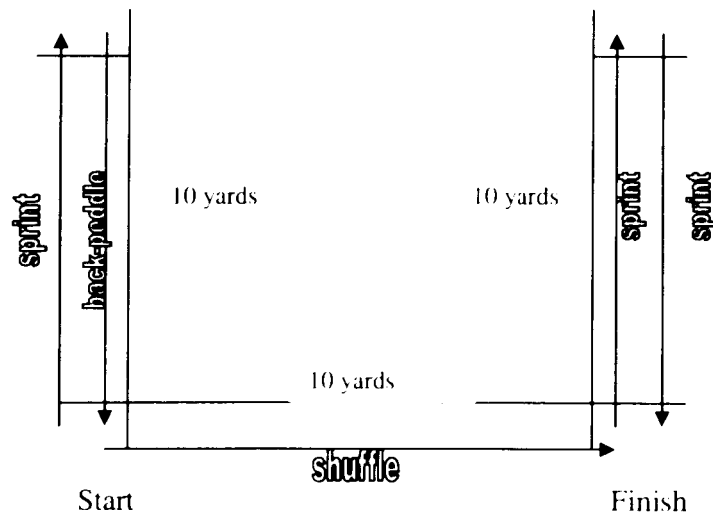


Figure 1. Start-Stop-Cut Test

### Procedures

Groups began study treatment the day following baseline testing. Extra time was taken during the first couple warm up sessions to ensure athletes adequately learned proper execution of each exercise. Each session began with attendance taken and relevant



discussion as needed concerning participant scheduling conflicts; feedback concerning procedures or injuries was encouraged and followed up on.

The team held captains' practices in the afternoons, Monday through Thursday, with the treatment groups completing their respective warm up immediately prior to practice 4 days a week. Baseline testing was conducted on Tuesday September, 28<sup>th</sup>, followed by two treatment sessions to finish the first week of the study. During the following 3 weeks, four sessions were held each week with a make up session held on Fridays for those that missed a session earlier in the week. Regular season practices began October 18<sup>th</sup>. Since team practice was held at the same time as captains' practices, this did not affect the warm up schedule. Post-study testing took place Monday October, 25<sup>th</sup>. Overall, the study treatment included 14 scheduled warm up sessions. Those who missed sessions were asked to make up those sessions on Fridays and Saturdays on their own or with others who missed sessions during the week.

Throughout the study, multiple participants were unable to attend one or more sessions. At the end of the study, there were two participants who were unable to make up one session, thus completing 13 sessions. Seven additional participants missed one or two sessions, but were able to make up those sessions throughout the study period. There was one participant in the high volume group unable to complete the study due to an injury unrelated to the study. In addition, there was one control participant and one low volume participant who were unable to attend post-testing. Statistical analysis was run using the final group numbers; therefore, the drop outs were excluded from data analysis. The co-investigator instructing the warm up was also limited to attending two sessions each week due to scheduling conflicts. Therefore, 7 of the 14 scheduled sessions were supervised.

Both treatment groups started the warm up with a 3-minute jog on the indoor track.

Upon completion of the jog, both groups formed short lines and began the prescribed dynamic exercises. For the order and description of each exercise, refer to Appendix G. The exercise list began with low intensity exercises and progressed in intensity throughout the warm up. Both groups performed the first set together. Upon completion of the first set, the low volume group was dismissed. The high volume group subsequently restarted at the beginning of the exercise list and proceeded to complete a second set. To reduce the effects of fatigue on exercise execution during the high volume group's second set, they were encouraged to take slightly more time between exercises as needed. Therefore, the high volume group added approximately 20 seconds of rest between exercises as they felt needed. The added rest had a minimal effect of the total time of the warm up. Each set took approximately 10 minutes to complete. Therefore, the low volume and high volume groups took approximately 10 and 20 minutes respectively to complete the warm up. Both groups completed their respective warm up prior to the start of practice. Therefore, neither treatment warm up interfered with the total practice time of each group.

Pre-study testing and all warm up sessions were held at the same location.

However, post-study testing had to be moved to another location within the building. This location had the same court surface as the one normally used. Therefore, the type of surface was held consistent between pre and post-testing for the standing long jump, start-stop-cut drill, and the proagility. However, for post-testing, the 30-meter was conducted on the same surface as the other tests instead of the indoor track surface. Due to the similarities in surface traction and rebound, it was not expected that 30-meter performance would be either enhanced nor restricted. Pre and post-testing were performed in the same order,

starting with the standing long jump, followed by the proagility, start-stop-cut drill, and finishing with the 30-meter. Participants were instructed to complete a similar general warm up as used in pretesting, which consisted of a 5-7 minute jog. Pre and post-testing were held at approximately the same time of day. All warm up sessions were performed at the same time each day with the exception of a few make-up sessions that the participants performed in the morning.

### Statistical Analysis

Statistical analysis was conducted using SPSS (PASW Statistics 18, 2009) software. Multivariate analysis of variance (ANOVA) was used to analyze baseline (pre-study) data to determine if there were any overall significant group differences in test performance to begin the study. Wilks' Lambda test results were used to determine significance. A  $p < 0.05$  was considered significant. Repeated measures ANOVA was used to analyze pre and post-study data determine if significant changes occurred within and among groups for each performance test. Treatment effects were evaluated by group, time, and group x time interaction on pre and post-study data for the standing long jump, proagility, start-stop-cut, and 30-meter performance tests.

## RESULTS

The purpose of this study was to compare the short-term training effects of two different DWU volumes on speed, power, and agility measures. As mentioned earlier, participants chose to either be in a control group or one of the two DWU training groups. The treatment participants were then randomly assigned within each weight class to either the high or low volume DWU groups. This was done to evenly distribute body types between the two training groups.

Although there appeared to be a noticeable difference between group means at the beginning of the study, MANOVA results indicated no significant differences between groups. This may be due to the low statistical power, the small sample population and group sizes. The control group means for all performance measures were slightly better than both treatment groups. There especially appeared to be meaningful differences in the 30-meter and start-stop-cut measures. These differences are displayed in the following graphs showing pre to post-test performances.

Results of the multivariate ANOVA are listed in Table 2. Wilks' Lambda test results showed no significant differences between groups at the beginning of the study. Therefore it was assumed that the three groups were relatively equal in performance level to begin the study. Since analysis results were not significant, there was no need for post hoc analysis.

Table 2. Multivariate ANOVA Tests of Baseline Data

Effect	Test	Value	F	Hypothesis df	Error df	<i>p</i>
Group	Wilks' Lambda	.638	1.007	8	32	.450

Each performance test was analyzed separately using a repeated measures ANOVA to determine the effectiveness of the study treatment within and between groups. Results are shown in Tables 3-7. The far left column in Tables 3-7 list Time, Group x Time, and Group. Data in the Time rows show results that determine if there is a significant difference between pre and post-study measures over time in the entire sample population. A significant result of time would indicate that the entire sample population showed a significant change in performance between the beginning and end of the study. Data in the Group x Time rows show results that determine if there was an interaction between time and treatment given to each group. In other words, these data indicate the differences in group responses over time based on pre and post-study test results. Any significant result in the Group x Time interaction of each test would indicate that there were significant differences among how the groups changed between the beginning and end of the study. Data in the Group rows show results that determine if there was a significant difference among the three groups based on overall performance across time. A significant result based on group would indicate that overall performance differences were significant enough to further differentiate groups by the end of the study.

Table 3 displays results for the standing long jump. The time effect was significant across groups for this performance test. This means that the sample population as a whole made significant improvements in the standing long jump between the beginning and end of the study. There were no results that indicate the groups were significantly different from each other. Group means for the standing long jump are displayed in Figure 2. The high volume group mean improved by 2.5 cm, the low volume group mean improved by 5.8 cm, and the control group mean improved the most at 6.5 cm.

Table 3. ANOVA for Standing Long Jump

	Sum Sq	Df	Mean Sq	F value	<i>p</i>
Time	274.566	1	274.566	8.036	.011
Group:Time	32.325	2	16.163	.473	.630
Group	701.183	2	350.591	1.064	.365

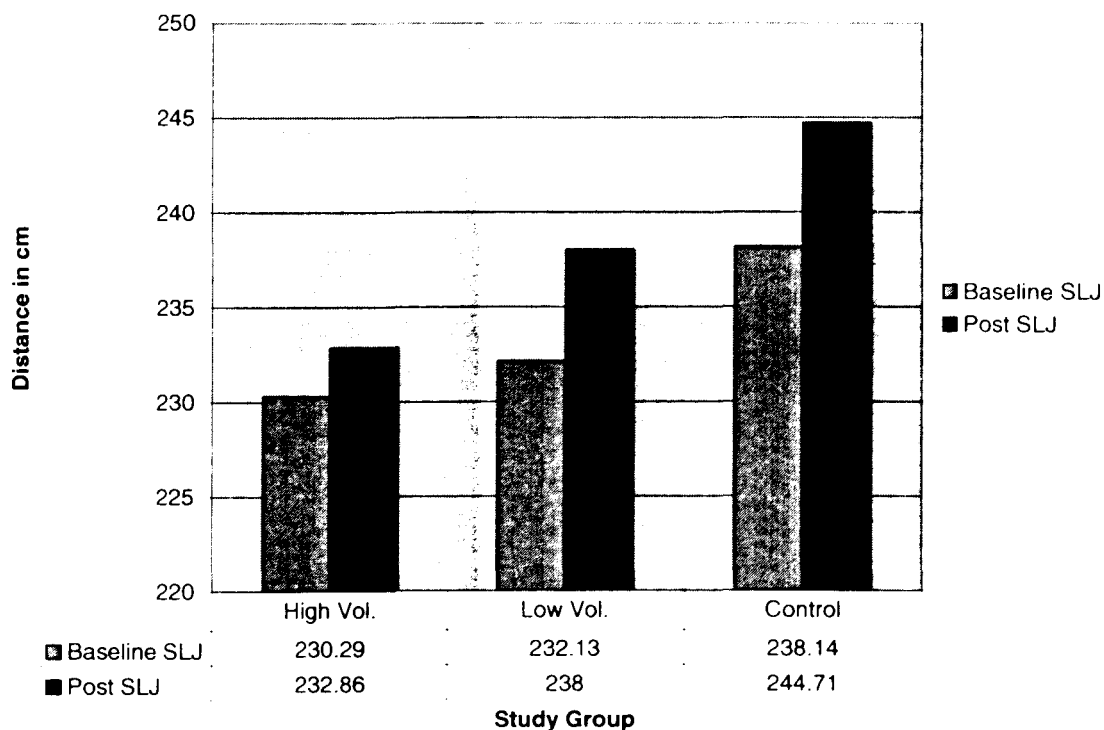


Figure 2. Group Means Standing Long Jump

Results of repeated measures ANOVA for proagility (Table 4) show no significant results of time, treatment group, or interaction. Therefore, changes within and between groups were not great enough to be of significance. All group mean changes were within

1.2%, equating to less than .10 second. Group means for the proagility are displayed in Figure 3.

Table 4. ANOVA for Proagility

	Sum Sq	Df	Mean Sq	F value	<i>p</i>
Time	.012	1	.012	1.645	.215
Group:Time	.014	2	.007	.947	.406
Group	.067	2	.034	.533	.595

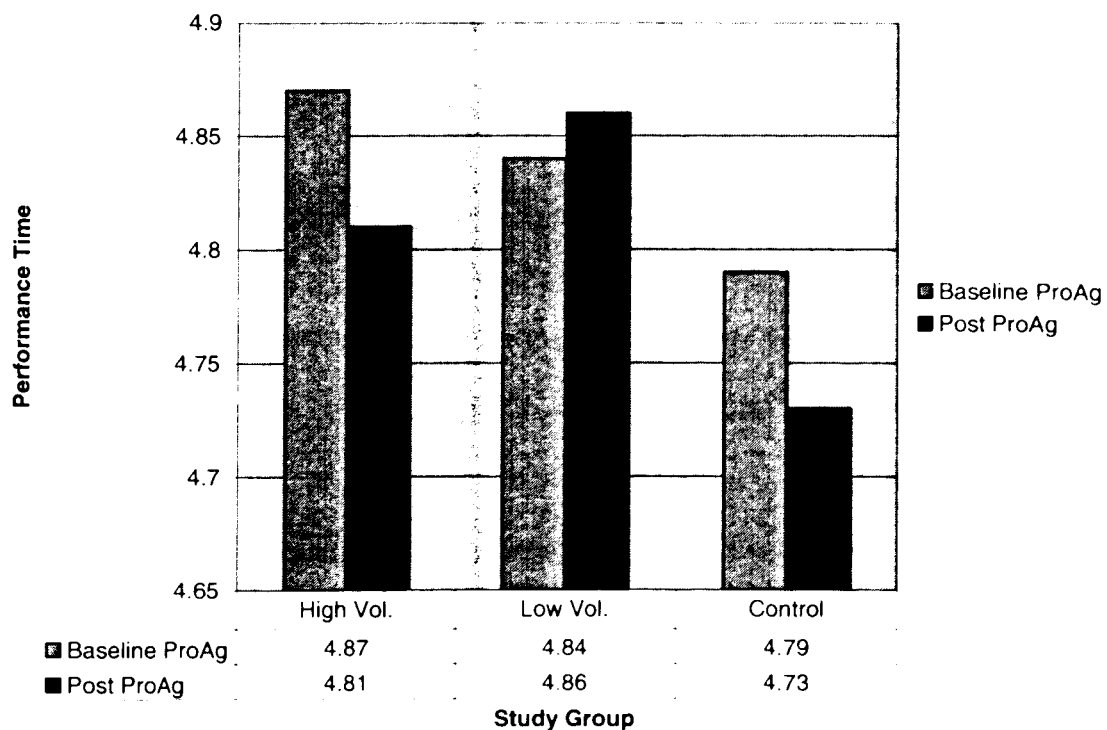


Figure 3. Group Means Proagility

Results of the start-stop-cut repeated measures ANOVA (Table 5) show a highly significant time effect across groups. However, there was no significant group or interaction effect. These results indicate that the sample population as a whole made significant improvement in this measure as indicated by the relative consistency of improvement among group means. Group means for the start-stop-cut are displayed in Figure 4. The change in group means were 3.2%, 4.5%, and 1.6% reduction in times for the high volume, low volume, and control groups respectively.

Table 5. ANOVA for Start-Stop-Cut

	Sum Sq	Df	Mean Sq	F value	<i>p</i>
Time	1.724	1	1.724	34.930	<.001
Group:Time	.277	2	.138	2.802	.086
Group	1.285	2	.643	2.116	.148

With a small sample population and subsequent group sizes, statistical power is relatively low. Therefore, it is more difficult to obtain statistical significance. The interaction effect for the start-stop-cut test did not reach the significance level of  $p < .05$ . However, since the interaction effect was relatively close, a repeated measures ANOVA was conducted with both treatment groups combined into one collapsed group. This was done to determine if there was statistical evidence that the treatment in general resulted in a significant differentiation in performance changes compared to the control group. Table 6 shows results of this ANOVA with a significant interaction effect ( $p = .044$ ). When the group means of both treatment groups were combined, the collapsed treatment group



showed an improvement in the start-stop-cut test of 4.0% compared to the 1.6% improvement found in the control group.

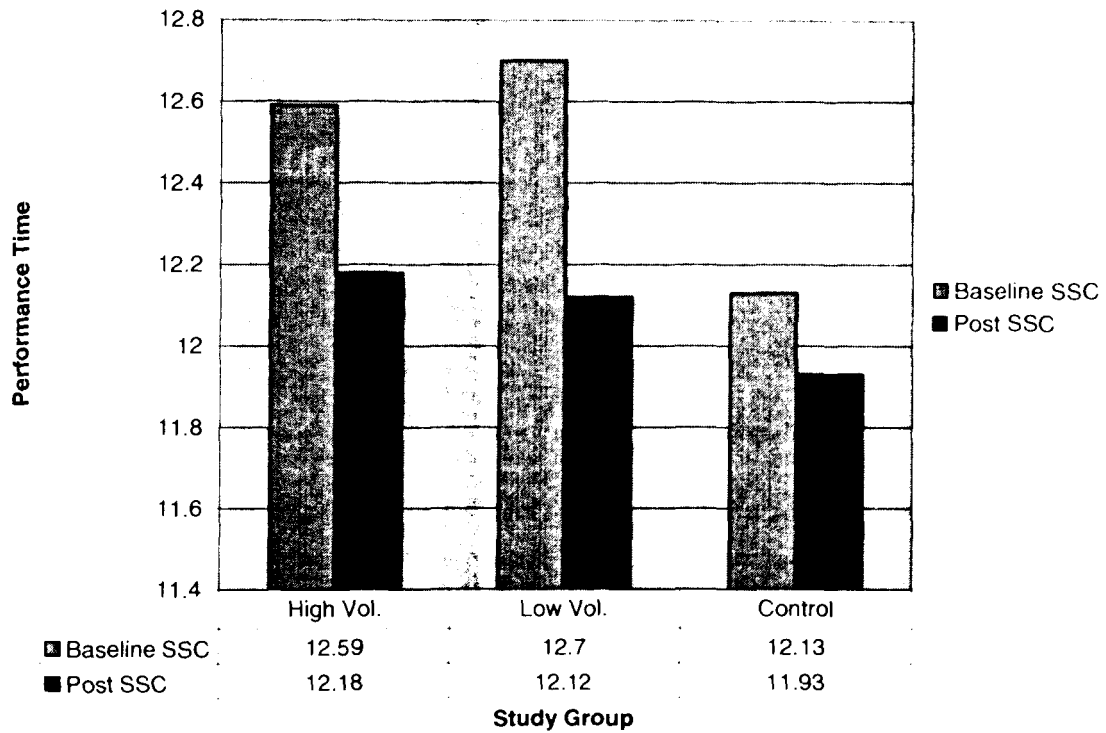


Figure 4. Group Means Start-Stop-Cut

Table 6. ANOVA for Collapsed Start-Stop-Cut

	Sum Sq	Df	Mean Sq	F value	<i>p</i>
Time	1.161	1	1.161	23.539	<.001
Group:Time	.228	1	.228	4.620	.044
Group	1.280	1	1.280	4.431	.048

The 30-meter repeated measures ANOVA results (Table 7) showed no significant time, group, or interaction effect. These results are consistent with the high and low volume group means showing a less than 1% change, equating to less than .05 sec, and the control group mean having no change. Group means for the 30-meter are displayed in Figure 5.

Table 7. ANOVA for 30-Meter

	Sum Sq	Df	Mean Sq	F value	<i>p</i>
Time	1.712	1	1.712	.003	.960
Group:Time	.007	2	.004	.547	.587
Group	.196	2	.093	1.525	.243

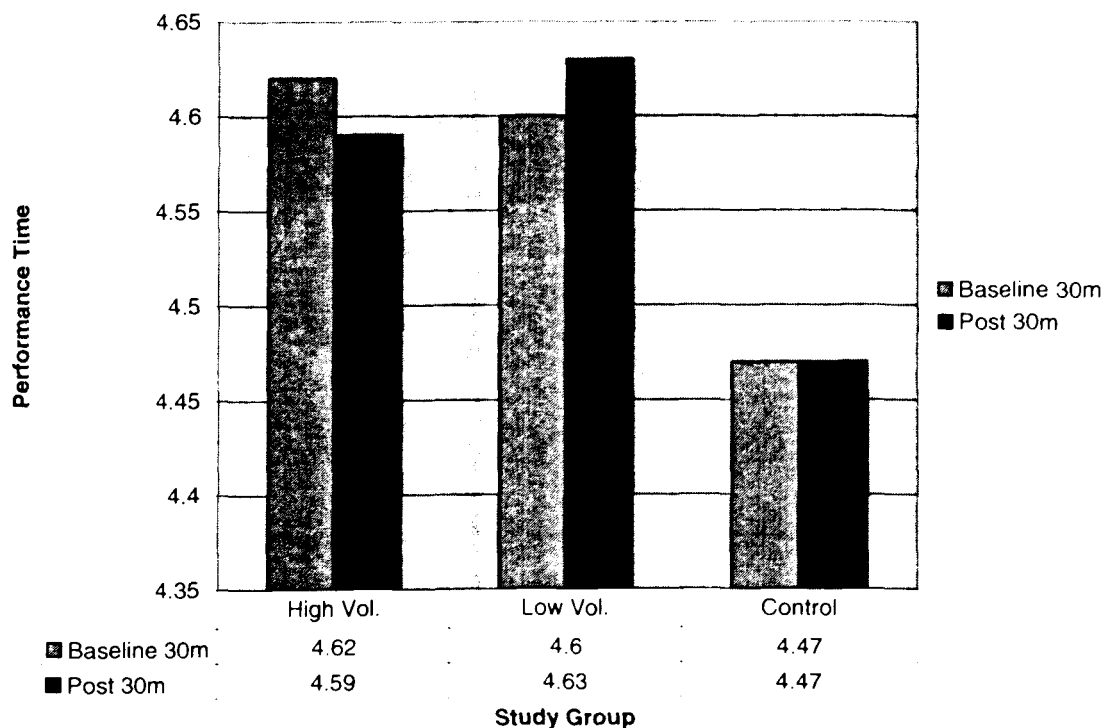


Figure 5. Group Means 30-Meter

ANOVAs were used to analyze pre and post-study performance for each test measure. Results indicated over time there were significant changes between pre and post-testing within the entire sample population in both the standing long jump and the start-stop-cut measures. ANOVA analysis for the proagility and 30-meter performance measures indicated no significant changes over time within or among groups.

## DISCUSSION

The purpose of this study was to compare the short-term training effects of two different DWU volumes on speed, power, and agility measures. Statistical analysis indicated no significant differences comparing short-term training adaptations among the three study groups. The only significant findings were a time effect within the entire sample population for the standing long jump and start-stop-cut measures. Both the high and low volume group means improved similarly. In addition, the control group receiving no treatment improved its mean similarly to the two treatment groups as well. There were no statistically significant changes found in the proagility and 30-meter test measures. With the similarity of performance changes between the control group and the two training groups, it may be suggested that study results fail to provide convincing evidence that either DWU volume was effective in producing short-term sustainable training effects. It is possible that factors other than the training warm up contributed to results found in performance changes such as testing effect, weight training, or influences from pre-season practices.

Results of the present study are inconsistent with those found by Herman and Smith (2008). Herman and Smith found significant increases in most performance measures for a DWU treatment group, and no change in most performance measures for an active control group employing a static-stretch warm up. The Herman and Smith study was also conducted daily prior to pre-season practices over a 4-week period. However, the present study employed four sessions per week compared to five by Herman and Smith. The DWU of the present study was moderately comparable to the DWU protocol used by Herman and Smith, with the present study employing a greater emphasis and volume on high velocity

and plyometric exercises. Herman and Smith provided supervision for all treatment sessions, the study period was slightly longer, and 5 sessions were conducted each week for a total of 20 sessions compared to a total of 14 sessions in the present study. In the present study, the co-investigator was able to oversee only 7 sessions, and not every participant completed a total of 14 sessions. It should also be noted that nine participants missed at least one scheduled session, and two of them were unable to make up one session. Those who were unable to attend a scheduled warm up were left to make up those sessions by themselves. It appears all participants in the Herman and Smith study that completed and were included in pre and post data analysis were present for all treatment sessions.

Chappell and Limpisvasti (2008) showed an increase in vertical jump performance and performance in a timed single-leg hopping task in Division I female athletes. Participants completed 36 warm up sessions over a 6-week period. This warm up, similarly to the present study, implemented exercises designed to enhance lower body power and dynamics. This study clearly employed a longer treatment period and more than twice the number of training sessions compared to the present study. Although performance measures showed a statistically significant improvement, it is unclear if the longer study length and greater number of training sessions caused those improvements. No control group was used. One group performed the warm up concurrent with regular season practice, and the other group performed the warm up concurrent with organized spring practice. Therefore, it's difficult to distinguish the influence between practice and warm up activities on performance changes in the absence of a control group. It is also unsure if groups participated in strength and conditioning sessions outside of sport practice.

It's important to account for and control influential external factors when possible.

Herman and Smith (2008) were able to ensure that all other training variables outside of the training warm up were held consistent among all participants. Participants were required to attend pre-season practices and supervised weight training sessions where all practice components and weight training protocols were designed to be identical for all participants regardless of group assignments or weight class. In the present study, participants were Division III athletes where coaches may not require mandatory attendance to pre-season practices and strength and conditioning workouts. This policy greatly reduces the ability of coaches and study investigators to control external factors such as variability in participants' self-guided adherence and commitment to preparatory activities for the upcoming competitive season. Greater accountability and control over groups in the present study may have provided more insight into factors causing the results of this study and the discrepancies with those found by Herman and Smith.

There were also additional limitations in the present study that occurred with the timing of the study period and the frequency of study treatments. The study began later than anticipated and therefore the length was reduced to 3 ½ weeks. To the researcher's knowledge there are no other similar studies employing a dynamic warm up that have been conducted over a period of less than 4 weeks. In addition, to maintain a study length of 3 ½ weeks, the study period was extended through the first week of regular season practice. During the first week of practice, the wrestlers incurred a high training and conditioning volume during practice that produced an observable fatigue and reduction in performance in treatment warm up sessions. This fatigue was also observed as participants returned for post-study testing.

Mandelbaum et. al. (2005) implemented a 15-20 minute, three times per week, neuromuscular training warm up that was implemented throughout regular season soccer practices. This study involved female youth, and results were compared over two consecutive seasons. Although there were no performance measures used in the study, there was a significant reduction in lower body injury occurrence compared to those teams not performing the training warm up. This study may provide support for employing a specific dynamic warm up that is sustained throughout the duration of a season to produce changes in athletic performance and neuromuscular coordination. The participants in the present study are obviously very different from the participants in the Mandelbaum et. al. study. In addition, the present study was conducted over a much shorter period with a much smaller number of participants.

Design, instruction, and execution of the DWU protocol followed suggestions provided by past researchers (e.g., Hewett et. al., 2001; Wilson & Flanagan, 2008) whenever possible. However, the limits placed on length, frequency, and timing of the study, and the inability of the co-investigator to attend half of the warm up sessions may all be factors that in part influenced the lack of performance improvements to an extent of distinguishing the treatment groups from the control group.

There are several studies that evaluate the success of resistance training, plyometric training, sprint training, and various combinations of resistance, plyometric, and sprint training on athletic performance. These studies employ various lengths of training periods that have produced significant changes. Mihalik, et. al. (2008) found significant changes in vertical jump performance after only 3 weeks in college aged men and women involved in club volleyball. The training involved a combination of resistance and plyometrics.

Herman and Smith (2008) found significant changes after only 4 weeks of dynamic warm up training. However, both groups in the Herman and Smith study also participated in supervised resistance training three times per week. Murray, et al. (2007) found that 4 weeks of specific isokinetic training resulted in significant changes in limb acceleration and standing long jump performance. Mujika, et. al. (2009) found a combination of alternating heavy-light resistance training was superior to 30-meter sprint training in 15-meter sprint performance. This study was conducted with only six sessions of each training protocol assigned to their respective group over a 7-week period. It appears that performance changes may occur over short-term training periods employing various training methods, training volumes and intensities, and number of training sessions. However, the exact causes of results found in the present study are unclear.

Testing effects may have influenced performance changes in the standing long jump and start-stop-cut tests. There was no statistically significant group interaction for the start-stop-cut test. However, a significant group interaction was found when both treatment groups were combined into one collapsed group and subsequently compared to the control group ( $p = .044$ ). The data were analyzed in this manner due to the relatively high significance found in the initial repeated measures ANOVA ( $p = .086$ ), and due to the low statistical power of small study groups. The results found by collapsing the treatment groups may indicate that DWU sessions had a practically significant positive effect in treatment groups on agility performance, although proagility results do not coincide with start-stop-cut performance.

Weight training may have also influenced test performance among groups. Although there was no mandatory weight training sessions for the team, most participants



involved in the study were participating in self-guided weight training. This weight training may have influenced participants' performance similarly among groups, thus the consistency in statistical results among all groups. Most participants in the study also regularly attended captains' practices. Captains' practice activities were similar for all wrestlers. Therefore, activities in practices may have had a similar influence on performance across all study groups, causing the consistency in performance results across all three groups. Additional research addressing the limitations of the present study is needed to more clearly determine sustainable training adaptations of a short-term DWU program.

## SUMMARY, CONCLUSIONS, AND RECOMMENDATION

The purpose of this study was to compare the short-term training effects of two different DWU volumes on speed, power, and agility measures. Results would then provide evidence of the short-term sustained performance adaptations of a DWU, and provide insight into prescribing an appropriate volume.

The results of this study fail to support short-term training adaptations of two different volumes of a DWU as implemented within the context of the study design. Results of the control group means were consistent with both training groups, which minimize any evidence of performance benefits of the DWU. Study results also do not support results found in a previous study examining the training benefits of a DWU. However, multiple limitations of this study such as study length and inconsistent compliance may have inhibited performance adaptations within the training groups.

Suggestions for future research should directly address the limitations encountered in the present study. NCAA Division III rules greatly restricted the investigators' ability to maintain consistency and control of external and internal factors. Conducting a similar study with participants who are subject to mandatory attendance and adherence to external activities would enhance consistency throughout all participants. It is also suggested to lengthen the study period and subsequently increase the number of training sessions to possibly elicit sustainable performance adaptations. Timing of the study should avoid a schedule concurrent with regular season practice in order to minimize fatigue during the late stages of the study treatment and post-study performance testing.

The importance of consistent and quality hands-on instruction should never be overlooked in any training and practice environment. Work schedule conflicts allowed the

co-investigator to oversee only half of the warm up sessions, leaving the remaining sessions to be lead by team captains participating in the study. In addition, participants absent from regularly scheduled warm up sessions attempted to make up those sessions on their own schedule and initiative.

Final numbers in each study group following participant drop-out were eight, seven, and seven for the low, high, and control groups respectively. With the variation in performance data of each group due to the range of weight classes and the lack of adequate numbers from each weight class, a larger and equally diversified sample population for each group would provide group means that are more meaningful and generalized to an outside population. The small sample population and subsequent small group numbers result in low statistical power, making it more difficult to achieve statistical significance. Larger groups with random assignment to all groups should also minimize baseline differences between groups and equally distribute physical talent and ability. The control group in the current study was self-selected. Participants in the control group were unable to accommodate the study treatment schedule, thus participating in the study as part of a control group.

Design recommendations for future research should also address the influence of strength training on performance adaptations when associated with a DWU. Employing one DWU group to include strength training, and another DWU active control group without strength training would differentiate the effectiveness of each training variable.

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## APPENDIX A. PERMISSION FOR TEAM PARTICIPATION

To whom it may concern:

Dan Senn has my permission to conduct his research project with the Concordia Wrestling Team.

Sincerely Coach Nagel

*Clay Nagel*

Head Wrestling Coach

Concordia College

901 8th St S

Moorhead MN 56560

Tel: 218-234-9121

E-Mail [cnagel@cord.edu](mailto:cnagel@cord.edu)

## APPENDIX B. USE OF FACILITIES PERMISSION

August 24, 2010

To whom it may concern:

Dan Senn has my permission to utilize the Concordia athletic facilities for the purposes of his thesis research study to include pre- and post-study testing, and administration of treatment protocols throughout the duration of the study in the 2010-11 school year. Any potential facility use conflicts should be addressed through Coach Nagel and Dave Klug (Facility Coordinator).

Larry A. Papenfuss, Ph. D.  
Director of Athletics

## APPENDIX C. INSTITUTIONAL REVIEW BOARD LETTER

**NDSU****NORTH DAKOTA STATE UNIVERSITY**

Institutional Review Board

Office of the Vice President for Research, Creative Activities and Technology Transfer  
NDSU Dept. 4000  
1735 NDSU Research Park Drive  
Research 1, P.O. Box 6050  
Fargo, ND 58108-6050Phone: 701-785-8295  
Fax: 701-785-8098E-equal/Equal Opportunity #1540106, 409  
Expires April 4, 2011

September 22, 2010

**Donna Terbizan**  
**Department of Health, Nutrition and Exercise Science**  
**BBFH**

IRB Expedited Review of: "Long-Term Training Effects of Dynamic Warm-Up Volume on Speed, Power, and Agility", Protocol #HE11034

Co-investigator(s) and research team: **Dan Senn**Research site(s): **Concordia College**Funding: **n/a**

The protocol referenced above was reviewed under the expedited review process (category # 4) on **9/17/2010**, and the IRB voted for:  approval  approval, contingent on minor modifications. These modifications have now been accepted. IRB approval is based on the original submission, with revised protocol and consent form (received 9/21/10).

Approval expires: **9/16/2011** Continuing Review Report Due: **8/1/2011****Please note your responsibilities in this research:**

- o All changes to the protocol require approval from the IRB prior to implementation, unless the change is necessary to eliminate apparent immediate hazard to participants. Submit proposed changes using the *Protocol Amendment Request Form*.
- o All research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others must be reported in writing to the IRB Office within 72 hours of knowledge of the occurrence. All significant new findings that may affect risks to participation should be reported in writing to subjects and the IRB.
- o If the project will continue beyond the approval period, a continuing review report must be submitted by the due date indicated above in order to allow time for IRB review and approval prior to the expiration date. The IRB Office will typically send a reminder letter approximately one month before the report due date, however, timely submission of the report is your responsibility. Should IRB approval for the project lapse, recruitment of subjects and data collection must stop.
- o When the project is complete, a final project report is required so that IRB records can be inactivated. Federal regulations require that IRB records on a protocol be retained for three years following project completion. Both the continuing review report and the final report should be submitted according to instructions on the *Continuing Review Completion Report Form*.
- o Research records may be subject to a random or directed audit at any time to verify compliance with IRB regulations.

Thank you for cooperating with NDSU IRB policies, and best wishes for a successful study.

Sincerely,

Teryl Grosz, Manager  
Human Research Protection Program

Last printed 9/22/2010 4:56:08 PM

NDSU is an equal opportunity institution.

## APPENDIX D. CONCORDIA APPROVAL

**RE: [Fwd: FW: IRB approval]**

Linda Scott [lscott@cord.edu]

Sent: Thursday, September 23, 2010 12:51 PM

To: dan.senn@ndsu.edu

Dan,

I reviewed your documents and you have my approval to go ahead with your study.

Best wishes on your study and the completion of your graduate work.

Linda Scott

Linda Scott, EdD, RN

Associate Professor

Chair, Institutional Review Board

Concordia College

Moorhead, MN 56562

(218) 299-4063

lscott@cord.edu

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## APPENDIX E. CONSENT TO PARTICIPATE

NDSU North Dakota State University  
Department of Health, Nutrition and Exercise Sciences  
Bentson Bunker Fieldhouse  
Fargo, ND 58108-6050  
701-231-7491

**Title of Research Study:** LONG-TERM TRAINING EFFECTS OF DYNAMIC WARM-UP VOLUME ON SPEED, POWER, AND AGILITY

**This study is being conducted by:** Principal investigator Donna J. Terbizan ([D.Terbizan@ndsu.edu](mailto:D.Terbizan@ndsu.edu)) and graduate student Dan Senn, ([dan.senn@ndsu.edu](mailto:dan.senn@ndsu.edu)).

**Why am I being asked to take part in this research study?** You are being asked to participate in this study because you are a healthy male wrestler on the Concordia College campus.

**What is the reason for doing the study?** The purpose of this study is to compare the long-term training effects of two different dynamic warm up volumes on speed, power, and agility performance measures. The results of this study will provide useful information on whether it is more beneficial to perform one or two sets of each warm up exercise based on the changes in performance.

**What will I be asked to do?** This study involves performing a prescribed warm up four days a week. The warm up will be performed prior to each weight training session. You will be assigned to one of three groups. One group will perform two sets of each warm up exercise, one group will perform one set of each warm up exercise, and one group will be instructed not to perform the warm up that is prescribed for the other two groups. To determine changes in athletic performance for the duration of the study, all you will complete four basic performance tests at the beginning and end of the study period. These tests will assess speed, power, and agility.

**Where is the study going to take place, and how long will it take?** This study will take place on the Concordia College campus in the Olson Indoor Athletic Complex. This study will take place throughout the duration of the pre-season and is scheduled to end with performance testing during the week of October the 18<sup>th</sup>.

**What are the risks and discomforts?** Risk of injury will be minimal if study protocol instructions are followed. The study testing and treatment involves short duration physical exertion. Physical harm and discomfort will be considered mild and as expected when beginning a new physical fitness routine. Discomfort is expected to last no longer than a few days from the initiation of the study. If needed, you can withdraw at any time.

**What are the benefits to me?** Participation in this study will provide you an opportunity to learn information about designing and executing warm ups that they may apply to their own training programs. By following warm up instructions, you may also enhance athletic performance. However, you may not get any benefit from being in this research study.

**What are the benefits to other people?** Results of this study may provide information that is beneficial to others planning a warm up. These results may be communicated to others through publication in a research journal.



**Do I have to take part in the study?** Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

**What will it cost me to participate?** There is no cost to participate in this study.

**What are the alternatives to being in this research study?** Instead of being in this research study, you can choose not to participate.

**Who will see the information that I give?** We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study, and stored in the principle researcher's office in a locked file cabinet. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private.

**Can my taking part in the study end early?** Yes, you may withdraw from the study at any time without completing the study.

**What happens if I am injured because of this research?** If you receive an injury in the course of taking part in the research, you should contact Dr. Donna Terbizan at [d.terbizan@ndsu.edu](mailto:d.terbizan@ndsu.edu) or 231-7792 or Dan Senn at [dan.senn@ndsu.edu](mailto:dan.senn@ndsu.edu) or (218) 791-6297. Treatment for the injury will be available including first aid, emergency treatment and follow-up care as needed. Payment for this treatment must be provided by you and your third party payer (such as health insurance or Medicare). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

**What if I have questions?** Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researcher, Dr. Donna Terbizan at 701-231-7792 or Dan Senn at (218) 791-6297.

#### **What are my rights as a research participant?**

You have rights as a participant in research. If you have questions about your rights, or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8908
- Email: [ndsu.irb@ndsu.edu](mailto:ndsu.irb@ndsu.edu)
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: [www.ndsu.edu/research/irb](http://www.ndsu.edu/research/irb).

#### **Documentation of Informed Consent:**

You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

You will be given a copy of this consent form to keep.

\_\_\_\_\_  
Your signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
Your printed name

\_\_\_\_\_  
Signature of researcher explaining study

\_\_\_\_\_  
Date

\_\_\_\_\_  
Printed name of researcher explaining study

## APPENDIX F. PAR-Q FORM

Physical Activity Readiness  
Questionnaire (PAR-Q)  
revised 2002

# PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and is strongly recommended for all people. It can help you stay healthy, prevent disease, and live longer. However, some people should be careful with their activity. They should be screened by a doctor before starting a new physical activity.

If you are planning to be more physically active, you should first do the PAR-Q. If you answer "YES" to any of the seven questions, you should talk to your doctor. If you are planning to be more physically active, you should first do the PAR-Q. If you answer "YES" to any of the seven questions, you should talk to your doctor.

Common sense is your best guide when you answer these questions. If you answer "YES" to any of the seven questions, you should talk to your doctor.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of any other reason why you should not do physical activity?

If  
you  
answered

**YES to one or more questions**

- Talk to your doctor about the results of the PAR-Q. Your doctor will help you decide if you should start a new physical activity.
- If you have a heart condition, you should only do physical activity that is recommended by your doctor.
- If you have a bone or joint problem, you should only do physical activity that is recommended by your doctor.

**NO to all questions**

- You are well enough to start a new physical activity. You should start a new physical activity.
- If you have a heart condition, you should only do physical activity that is recommended by your doctor.
- If you have a bone or joint problem, you should only do physical activity that is recommended by your doctor.

**DELAY BECOMING MUCH MORE ACTIVE**

If you are planning to be much more active, you should talk to your doctor first. Your doctor will help you decide if you should start a new physical activity.

**PLEASE NOTE**

- The PAR-Q is not a medical test. It is only a screening tool.
- The PAR-Q is not a substitute for a medical examination.

**No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form**

With thanks to the following people for their help in developing the PAR-Q: ...

PAR-Q Form  
Name: \_\_\_\_\_  
Address: \_\_\_\_\_  
City: \_\_\_\_\_  
Province: \_\_\_\_\_  
Postal Code: \_\_\_\_\_

**Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions**

Source: Physical Activity Readiness Questionnaire (PAR-Q) © 2002. Used with permission from the Canadian Society for Exercise Physiology, www.csep.ca.

## APPENDIX G. DYNAMIC WARM UP PROTOCOL

General warm up protocol.

Each warm up session will begin with a light three minute jog.

Dynamic warm up protocol.

1. Ankle bounds- This exercise is a combination of single leg bounding and ankle flex forward hops (Bjornaraa, 2001). An alternating single leg bound is performed with the primary movement occurring at the ankle joint, as opposed to the hip joint. Feet are maintained in close proximity to each other and legs maintained almost completely straight. A forward bounding movement is performed by plantar flexing the feet and bouncing on the balls of the feet. The focus of movement performance is minimizing ground contact time, powerful plantar flexion, and covering the distance goal as quickly as possible. Each set will be performed a distance of 20-meters.
2. Power skips- These are similar to regular skips. The difference is the tempo, and the arm and leg actions are much more aggressive. Elbows are kept at ninety degrees flexion with the hands moving from hips to shoulder height. Knees are driven to a point where the femur is at least parallel with the ground. The focus of this exercise is to minimize ground contact time, powerful rotation at the shoulder and hip, with a high number quality repetitions performed throughout the distance goal (Bjornaraa, 2001). Each set will be performed for 20-meters.
3. Skips for height- Similar to power skips (Bjornaraa, 2001), except the tempo is slower and ground contact times are longer to accommodate for higher force production and higher skip height. Athletes will attempt to maximize height on each

repetition. The focus is to perform quality repetitions throughout the set distance.

Each set will be performed for 20-meters.

4. Backwards power skips- same as power skips (Bjornaraa, 2001), except performed moving backwards. Each set will be performed for 20-meters.
5. Lateral crossover running- This exercise is similar to high knee carioca (Fredrick & Szymanski, 2001), except the lateral movement sequence does not include a side step behind the lead leg. If moving to the left, perform a side step with the left foot, following with the right leg driving up and towards the direction of movement, crossing in front of the left leg. The upper body rotation is minimized while the hips oscillate between facing lateral and to the direction of movement. The focus of performance is good rotation towards the direction of movement, aggressive pulling with the lead leg and good drive with the trailing leg. Athlete must perform movement in a bounding action, maximizing lateral distance with each repetition. Each set will be performed for 20-meters.
6. Carioca- Athlete will perform a lateral cross-stepping movement while freely rotating the hips and minimizing rotation of the upper body. If moving to the left, the right foot crosses over in front of the left and the hips turn toward the direction of movement, the left leg then side-steps, followed by the right foot crossing behind the left foot and the hips turn away from the direction of movement. This series of movements is repeated as quickly as possible using short steps, and emphasizing quick, full rotation of the hips. Each set will be performed for 20-meters.
7. Backwards crossovers- Same as crossover running movement, except movement is in the backwards direction as opposed to lateral, and each repetition alternates

between a right and left crossover step. The athlete will perform an alternating left-over-right to right-over-left movement pattern in a backwards direction. The focus of this exercise is good side-to-side hip rotation, leg coordination and change of direction with each repetition. Each set will be performed for 20-meters.

8. **Mountain climbers-** Athlete assumes a "spiderman" position on the ground with low shoulders and hips, and hands in a pushup position. Begin with one leg flexed and abducted and externally rotated at the hip and the other leg straight back. The athlete will then alternate foot/leg position as quickly as possible without compromising low shoulder and hip position and leg range of motion. The exercise is very similar to a spiderman crawl except the leg action is much more aggressive with a much faster tempo. The focus in this exercise is to maintain a low shoulder and hip position, powerful hip flexion, abduction, and external rotation, and perform as many repetitions as possible within the time goal. Each set will be performed for 20-seconds.
9. **Lunge-switch jumps-** Athlete will assume a lunge or stride position, keeping the knee of the forward leg directly above the ankle, and the rear leg off of the ground. While in the lunge position, the athlete will be instructed to perform an isometric contraction as if attempting to pull their feet together. This contraction will be held for a one-to-two second count in-between jumps. Upon command, athlete will jump from the lunge position and alternate leg position. The focus of this exercise is strong isometric contractions, jumping for height, and quick leg position alternation (Bjornaraa, 2001). Each set will consist of five repetitions on each leg for a total of ten.

10. Skaters- Similar to a dry-land skating motion. Athlete will begin on right leg and perform a forward and lateral bound, landing on the left leg, and squatting down into the landing until hips are in a low position and femur is nearly parallel with the ground. The athlete will then immediately change direction and bound to the diagonally to the right. The focus of this exercise is powerful takeoff for maximal diagonal distance, quick change of direction, and controlled landings (Bjornaraa, 2001). Each set will be performed for 20-meters.
11. Squat-jump burpees- Athlete assumes a lying prone pushup position. An explosive pushup is performed with the knees driven towards the chest, and recovering in a low squat position. From this position a powerful squat jump is immediately performed, followed by a landing that settles back into the squat position, and then immediately dropping back into the lying prone pushup position where the sequence is immediately repeated. The focus is powerful jumps and maximizing jump height, controlled landings, and powerful pushup movements (Crotin, 2009). Each set will include ten repetitions.
12. Forward-Backwards Ladder- The athlete will perform a short series of forward accelerations followed by a quick deceleration and stop, and then backwards acceleration, backwards deceleration and stop, forward acceleration, and so forth. The focus is hard acceleration, quick stops, and quick changes of direction. Five cones will be placed 5-meters apart (Figure 6)

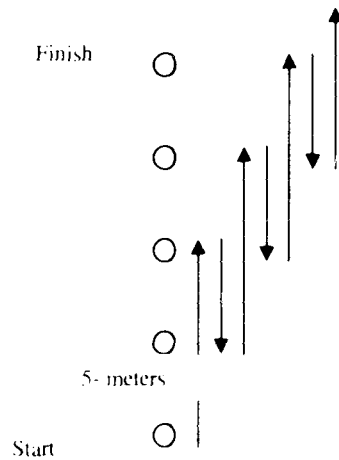


Figure 6. Forwards-backwards Ladder

13. Zig-zag drill- Athlete will perform a series of cut and go maneuvers, zig-zagging around the outside of the cones. Focus is on quick acceleration and deceleration, and performing solid cuts around the cones by planting on the outside foot, while maintaining a low center of gravity. Cones will be placed six cones will be placed 5-meters apart providing a 45-degree change of direction (Figure 7).



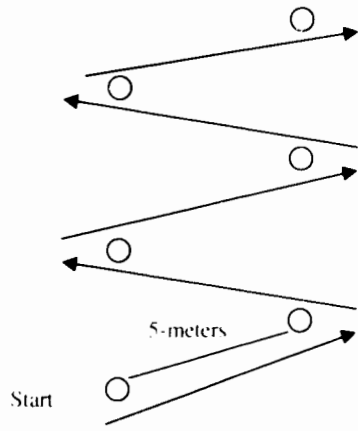


Figure 7. Zig-Zag Drill