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STATIC VERSUS DYNAMIC STRETCHING EFFECT ON AGILITY
PERFORMANCE

by

Patrick Troumbley

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health, Physical Education and Recreation

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2010

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ABSTRACT
Static Versus Dynamic Stretching Effect on Agility Performance

by

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Utah State University, 2010

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Department: Health, Physical Education and Recreation

The purpose of this study was to compare effects of static and dynamic stretching on explosive agility movements, and to examine the effect of the interaction of dynamic and static stretching prior to explosive agility movements. Fourteen men and 10 women performed the different warm-up protocols, including no warm-up (NWU), static stretching (SS), dynamic stretching (DS), and dynamic stretching with static stretching (DS+SS). The T-Drill was used to assess agility. The results indicated no difference between the NWU and SS conditions (effect size = 0.40, $p = 0.06$), as well as no significant difference between the NWU and DS+SS conditions (effect size = 0.01, $p = 0.48$), and the SS and DS+SS conditions (effect size = 0.40, $p = 0.06$). Statistically significant differences were found between the NWU and DS conditions (effect size = 0.45, $p = 0.03$), the SS and DS conditions (effect size = 0.85, $p < 0.001$), and the DS and DS+SS conditions (effect size = 0.40, $p = 0.03$). Agility test times, in order from fastest to slowest, were (a) dynamic stretching (10.87 ± 1.07 s), (b) dynamic stretching + static

stretching (11.41 ± 1.26 s), (c) no warm-up (11.42 ± 1.21 s), (d) static stretching (11.90 ± 1.35 s). Dynamic stretching resulted in the fastest agility test time. Static stretching resulted in the slowest agility times. The benefits of dynamic stretching may have been diluted when followed by Static Stretching, and the agility test time was the same as if no form of stretching was completed. Static stretching prior to agility is not recommended as it has a negative effect on the stretch shortening cycle, and agility. The results support the use of dynamic stretching prior to agility performance.

(62 pages)

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Patrick Troumbley

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CHAPTER I

INTRODUCTON

The pre-event warm-up has been common practice for many years. The warm-up is important to prepare the body for ensuing physical activity (Thomas, 2000). The primary aims of the warm-up are to decrease the possibility of injury during physical activity and to achieve the highest level of performance possible during the same event. Traditionally static stretching has been a main element of the pre-event warm-up (Church, Wiggins, Moode, & Crist, 2001; Young & Behm, 2003). Pre-event static stretching has been prescribed to prevent injury by increasing the range of motion about a joint or series of joints (Hendrick, 2004), and to improve performance in dynamic activities. Dynamic stretching has recently been prescribed by strength and conditioning professionals (Gambetta, 1997) for pre-event stretching. This increase in prescription is due to recent evidence that suggests that pre-event static stretching has a negative effect on some measures of performance, such as: strength (Fowles, Sale, & MacDougall, 2000; Kokkonen, Nelson, & Cornwell, 1998), jumping (Cornwell, Nelson, Heise, & Sidaway, 2001; Young & Behm, 2003) and sprint performance (Fletcher & Annes, 2007; Fletcher & Jones, 2004).

Sporting events involve various modes of movement. In athletic events (such as: soccer, football, basketball, & racquet sports) the athlete sprints, stops and changes direction rapidly. A mere tenth of a second can mean the difference in winning or losing. Plisk (2000) defined agility as “The ability of the body or body parts to explosively brake,

change direction, and accelerate again rapidly under control.” Agility and power activities use stored energy from the stretch-shortening cycle.

There are two theories as to why static stretching has a negative effect on sprint speed and power. It is believed that the decrease in performance measures is linked to a decrease in the stiffness in the musculotendinous unit that results in an increase in tendon slack, that requires more time to be taken in when the muscle contracts. This tendon slack results in a less effective transfer of force from the muscle to the lever (Avela, Kyrolainen, & Komi, 1999; Kokkonen, Nelson, & Cornwell, 1998; Wilson, Wood, & Elliot, 1991). In addition, static stretching may affect the neurological sensitivity. This decreased neurological sensitivity results in decreased neural drive to the muscle that equates to decreased muscle activation in the stretch reflex (Avela et al., 1999; Vujnovich & Dawson 1994). The amortization phase is the transition between the eccentric loading and the initiation of the concentric muscle action. To make use of the stored energy of the eccentric loading, the amortization phase must have a very short duration. If the amortization phase lasts too long the stored energy from the eccentric phase is lost and dissipated as heat (Potach, 2004). This results in decreased performance. Two sources of force production in the stretch-shortening cycle are the series elastic component of the mechanical model, and the neurophysiological element known as the stretch reflex (Plisk, 2000; Potach, 2004; Potach & Chu, 2000). Agility consists of several components. They are: acceleration, braking, and change of direction. Static stretching was found to have a negative effect on acceleration (Fletcher & Jones, 2004; Nelson, Driscoll, Landin, Young, & Schexnayder, 2005). When static stretching follows the general warm-up, it was found to dilute the effectiveness of the general warm-up (Young & Behm, 2003).

As athletes prepare for performance, the chosen method of warm-up should best prepare the athletes for performance in the following activity. The warm-up should comprise a general warm-up, a stretching to increase joint range of motion, and sport specific activity (Young & Behm, 2002). A warm-up that utilizes static stretching makes the athlete stop and sit after the general warm-up which may result in decreased body temperature and then the athlete would move into practicing sport specific movements. Dynamic stretching has been suggested as the main technique of stretching in the pre-event warm-up before high speed, and power activities (Fletcher & Jones, 2004; Little & Williams, 2004; Young & Behm, 2003).

In sports where agility is a key movement, little research has been done to determine which method of pre-event stretching (static or dynamic) elicits the greatest agility performance. In a review of literature on stretching, Herbert and Gabriel (2002) suggest that further research should be completed to draw conclusions that are more accurate on the effects of stretching on athletic performance.

Purpose

The increasing evidence of the negative effects of pre-event static stretching as well as the increasing prescription of the dynamic warm-up make it important to determine which type of warm-up protocol will be the most effective in preparing for sporting events that involve agility movements. The purpose of this research was to determine if pre-event static stretching (SS), dynamic stretching (DS), or the interaction of the two warm-up protocols (SS+DS) influenced performance outcomes of agility as measured by the T-Drill. The aim was to determine which method of stretching was

more appropriate prior to agility performance. The Paffenbarger Physical Activity Questionnaire (Paffenbarger, Hyde, Wing, & Hsieh, 1986; Paffenbarger, Wing, Hyde, & Jung, 1983) was used to determine if pre-event static stretching or dynamic stretching had a greater influence on participants due to fitness level. It was hypothesized that the dynamic warm-up protocol would result in an improved performance over a static stretching protocol and a no warm up group. This was hypothesized because the dynamic warm-up more closely mimics the specific movements of the agility test and is consistent with the principle of specificity. A secondary hypothesis was that static stretching would have a negative effect on agility performance as compared to no warm up group. The secondary hypothesis was based on two theories. The increase of range of motion would increase the slack of the musculotendinous unit, which would increase the amortization phase and as a result dissipate the stored energy of the stretch-shortening cycle (Wilson et al., 1991). Static stretching has an effect on the neurological sensitivity which results in decreased neural drive to the muscle, and decreased muscle activation in the stretch reflex (Avela et al., 1999; Vujnovich & Dawson, 1994). A third hypothesis was that static stretching would dilute the effects of the dynamic stretching when combined in a protocol (Young & Behm, 2003). The use of the Physical Activity Questionnaire would aid in more accurate prescription of pre-event stretching when applied to fitness level.

Significance

The results of this study along with the current research in this area might help coaches and strength and conditioning professionals make a more accurate prescription of the most effective method of pre-event stretching (static or dynamic) in the warm-up for

agility sports. The outcome of this study might help athletes be prepared to achieve maximum performance in agility sports.

CHAPTER II

REVIEW OF LITERATURE

This review of literature will examine the topic and relevant literature associated with pre event preparation and the effects of various modes of stretching. The topics reviewed are (a) the purpose of the pre event warm-up, (b) static stretching, (c) effect of static stretching on performance, (d) static stretching for injury prevention, (e) dynamic stretching, (f) pilot study, (g) summary, (h) purpose of research, (i) research objectives.

Purpose of Pre-event Warm-up

The purpose of the warm-up is important for proper functioning and optimum performance. A warm-up is designed to increase the core temperature in order to prepare the body for physical exertion. The warm-up usually consists of a gradual increase of intensity while also progressing from general to specific movements. There are two main types of warm-up: passive and active. Some of the passive warm-up techniques include the use of heat packs, hydrotherapy, and massage (Wathen, 1987). The passive warm-up is used mainly in sports medicine and physical therapy as preparation for rehabilitation exercises. The active warm-up is the used for pre-event preparation. The active warm-up utilizes the athlete's muscular power to perform light exercises that increase core body temperature without fatiguing the participant. The duration of the warm-up exercises should not be very long or of high intensity. The active warm-up consists of general and specific movements (Wathen, 1987). The general warm-up consists of simple motor activities (i.e., a light jog or calisthenics) that gradually increase in intensity and pace.

The calisthenics are specifically chosen to prepare the body for exercise by increasing core temperature. The specific warm-up includes movements that are particular to the activity (Wathen, 1987), and prepare the participant by mimicking the specific movement patterns of the activity that follows. The specific warm-up consists of a rehearsal of the movements and techniques used in the event. The purpose of utilizing the sport specific movements is to stimulate the nervous system and prepare the muscles, joints, tendons, and ligaments for the activity.

Young and Behm (2002) described three important components of the pre-event warm-up. These are (a) low intensity aerobic activity that is general in nature, to increase core temperature and improve neuromuscular function; (b) stretching the involved muscles to increase joint range of motion (ROM) and decrease muscle stiffness by inducing the relaxation response, and (c) rehearsal of the sport specific skill of the activity. Wathen (1987) also presented similar guidelines for the warm-up. These are (a) activity to increase core temperature to the point of sweating - but not to fatigue, (b) specific movement patterns, and (c) decrease of intensity 10 - 15 min before competition, with complete cessation 5 min before competition, (d) the better conditioned athletes require more warm-up time; and (e) some type of stretching integrated with the aerobic component. To make sure the participant is adequately prepared for competition, the warm-up should follow the guidelines of Young and Behm (2002) and Wathen (1987).

The purpose of the warm-up routine is to prepare the body for the physical activity. If properly executed the warm-up elicits the physical changes in preparation for the activity. The warm-up prepares the specific energy system that will be used in the activity. Muscle fibers experience an increase in extensibility and elasticity, which leads

to increased force production and increased muscle contraction velocity. These increases in force production and contraction velocity translate into improved strength, speed, and power. The increase in temperature leads to an increase in joint lubricant, which reduces joint friction and elicits improvements in range of motion (ROM). The warm-up also promotes psychological focus as well by the rehearsal of sport specific movement patterns. The sport specific movements activate muscle memory and prepare the central nervous system for the needed motor unit activation and coordination (Smith, 1994). Wathen (1987) suggested that by progressively adjusting the body to the activity and intensity, the risk of soft tissue injury may be reduced.

Static Stretching

There are a variety of stretching techniques, such as; static stretching, ballistic stretching, passive stretching, and proprioceptive neuromuscular facilitation. In these stretching techniques, the person being stretched is either active (self-stretched) or passive (assisted). The aforementioned stretching techniques are effective at increasing joint range of motion (Shrier, 2004). Static stretching is used to stretch muscles, and is performed by slowly lengthening a muscle to an elongated position, to the point of discomfort not pain (Anderson & Burke, 1991). The static stretch is held in the fixed position for 15-30 s (Ogura, Miyahara, Naito, Katamoto, & Aoki, 2007).

Effect of Static Stretching On Performance

Static stretching's effectiveness to promote optimal performance, in high intensity explosive type activities, has been debated (Moss, 2002). Many exercise professionals

and coaches have prescribed static stretching as part of the warm-up routine. In many recent investigations it has been found that pre event static stretching has a negative effect on performance (Behm, Bamcurey, Cahill, & Power, 2004; Behm, Button, & Butt, 2001; Boyle, 2004; Cornwell et al., 2001; Fletcher & Annes, 2007; Fletcher & Jones, 2004; Fowles et al., 2000; Kokkonen et al., 1998; McMillian, Moore, Hatler, & Taylor, 2006; Ogura et al., 2007; Young & Behm, 2003).

Young and Behm (2003) compared the effects of various warm-up protocols on concentric jump height and drop jump height. The warm-up protocols compared were a control, which consisted of 3 min walking 5 squats, and 5 heel raises with no added resistance (29.5 ± 3.7 cm, 26.5 ± 5.5 cm), run (30.2 ± 3.7 , 27.7 ± 6.4 cm), stretch (28.3 ± 3.5 cm, 25.7 ± 5.9 cm), run + stretch (29.2 ± 3.2 cm, 26.5 ± 5.6 cm), and run + stretch + jumps (30.2 ± 3.4 cm, 27.8 ± 5.9 cm). The run and run + stretch + jumps warm-ups produced the best explosive force and jumping performances. The static stretching warm-ups always produced the lowest values. When comparing the control to all the stretch warm-up protocols, the control produced better performance. When the run warm-up was compared to the run + stretch warm-up, the run warm-up produced higher jump performance, 3.4% and 3.2% difference. The static stretching diluted the effects of the run warm-up, which resulted in decreased jump performance.

Moss (2002) indicated that static stretching prior to highly intense activities may inhibit performance. This comes from a reduction in power and strength, which is from a decrease in muscle activation and contractile properties at the cellular level. Power movements also utilize energy from stretch-shortening cycle. If the transition (amortization phase) between the eccentric loading and the initiation of the concentric

muscle action is not fast enough the stored energy, from the eccentric loading, is not used and is dissipated as heat (Potach, 2004). The two sources of force production in the stretch shortening cycle are the series elastic component of the mechanical model, and the neurophysiological element (the stretch reflex). The decrease in performance measures is believed to be linked to a decrease in the stiffness in the musculotendinous unit, which results in tendon slack. The increased tendon slack requires more time to be taken in as the muscle contracts. The increased tendon slack results in a less effective transfer of force from the muscle to the lever (Avela et al., 1999; Kokkonen et al., 1998; Wilson et al., 1991). It is also believed that static stretching affects the neurological sensitivity. This results in a decrease in neural drive to the muscle, and in the end, leads to decreased muscle activation in the stretch reflex (Avela et al., 1999; Vujnovich, & Dawson 1994). Moss (2002) and Shrier (2004) recommend avoiding static stretching prior to high intensity, explosive activities. Shrier (2004) does recommend static stretching as part of a cool down or away from the event. The cool down assists muscle relaxation, helps the removal of waste products, and lessens muscle soreness (Best, 1995).

Static Stretching for Injury Prevention

Static stretching has been prescribed as a pre-event activity for injury prevention for many years. Pope, Herbert, Kirvan, and Graham (2000) studied male army recruits to determine if in fact static stretching reduced the risk of injury during physical activity. It was found that pre-event stretching did not produce clinically meaningful reductions in the risk of injury. Pope also found that the greatest predictor of injury risk was poor aerobic fitness as measured by the twenty-meter progressive shuttle run. In a review by

Shrier, Saber, and Garrett (1999) a number of reasons were given as to why stretching before an event or exercise would not prevent injury. An increased range of motion would not benefit certain activities, such as long distance running and cycling since muscle length and range of motion is not an issue. Stretching would not affect muscle compliance during the eccentric activities, where it is believed most injuries occur. Stretching could also cause micro traumas to the muscle being stretched. Chronic micro traumas to a muscle could weaken it and predispose it to injury. The increase in stretch tolerance may mask the pain that would elicit muscular reaction to prevent an injury. Herbert and Gabriel (2002) also determined, through a review of literature, that static stretching did not produce significantly meaningful reductions in the risk of injury. They also determined that static stretching did not reduce the effects of delayed onset muscle soreness.

Dynamic Stretching

Professionals are increasing their support of the dynamic stretching as the most effective way to prepare the athlete for the demands of their sport (Gambetta, 1997). Dynamic stretching uses momentum and active muscle contractions to produce a stretch. Dynamic stretching is comprised of movements that are similar to those in which the participant will engage (Mann & Jones, 1999). Fletcher and Jones (2004) described dynamic stretching as a controlled movement through the active range of motion for each joint. Dynamic stretching utilizes movements that mimic the specific sport or exercise in an exaggerated yet controlled manner. Dynamic stretching is often included as part of the warm-up or preparation for a sports event. Dynamic stretching is different from

ballistic stretching which is repeating small bounces at the end of the range of motion. In a study conducted by McMillian et al. (2006), dynamic warm-ups demonstrated an improvement in power and agility measures as compared to a static stretch and no warm-up protocols. As in all warm-up protocols, the dynamic warm-up should start at a lower intensity and gradually increase to higher intensities of the movement pattern. This is important because dynamic warm-up protocols require balance and coordination. The dynamic warm-up fulfills the components established by Young and Behm (2002) of a pre-participation warm-up routine. An additional benefit may be that dynamic warm-up enables participants to be actively involved, focusing their energy into their warm-up routine and the following event. Static stretching in the pre-event warm-up may allow time for conversation, which will hinder the psychological focus of the athlete and may affect the quality of the static stretching routine. The dynamic warm-up protocols vary in the type of exercise used and in length of the warm-up session. The main purpose of the dynamic warm-up should be to mimic the sport specific movement patterns (Boyle, 2004). According to Gesztesi (1999), a dynamic warm-up before the explosive activity reduces the likelihood of injury. This is because the dynamic warm-up permits the muscles to tolerate stresses of the activity with a reduced level of strain. The effective warm-up routine may consist of light intensity running and would be followed by a dynamic stretching. The running should increase the core temperature and lubricate joints (Roth & Benjamin, 1979), and the dynamic stretching mimics sport specific movements of the following activity. This protocol prepares the central nervous system for the necessary coordination and activation of motor units (Smith, 1994). Injury may

be prevented because the practice of the movement patterns may eliminate awkward and inefficient movements (Hedrick, 2000).

McMillian et al. (2006) analyzed (a) leg power (5-step jump), (b) total body power (medicine ball throw) and (c) agility (modified T-Drill). Agility was the primary measure of this study, as it is a component of many different athletic events. Measuring agility as the only performance outcome decreased the possibility of contaminating the data due to the exertion required in multiple performance measures. Leg power and speed are two components of agility. Both activities draw on stored energy from the stretch shortening cycle. McMillian et al. (2006) used a modified T-Drill to measure agility. This was done to emphasize the lateral movement portion. The forward and backward-run portions (between cones 1 & 2) of the T-Drill were set at 4.57 m, not the 9.14 m established by Semenick (1990, 1994). The decreased distance did not allow the participants to achieve a higher velocity, which also requires greater braking ability. To maintain reliability and validity the T-Drill for this research the parameters were consistent with those established by Semenick (1990, 1994) as the T-Drill has been previously established as valid measure of leg speed and power (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000). The standard parameters are more relative to agility sports as the participants are able to attain a higher velocity. Attaining the higher velocity results in higher levels of eccentric loading during the braking phase and consequently allows for higher levels of stored power, from mechanical and neurological models of the stretching shortening cycle. The increased initial velocity will more likely create higher levels of stored energy in the eccentric, braking for the transition to the rapid change of direction.

Pilot Study

The pilot study was conducted as a class project in a course instructed by Dr. Eadric Bressel (see Appendix C).

Confounding Variables of the Pilot Study

The lack of significant improvement in terms of agility performance within this study may have been attributed to several confounding variables. The small sample size is the main factor attributed to not finding a statistically significant difference in the means of the warm-up protocols. Another factor is that the participants were not reminded of the importance of maximal effort nor was there any verbal encouragement during the testing procedure. Although maximal effort was discussed in the familiarization process, failure to provide a reminder prior to testing may have influenced the motivation of the participants and consequently the measured performance times. Verbal encouragement and reminder of the importance of maximal effort was utilized in testing. In the pilot study the speed of the T-Drill was assessed with a stopwatch. To decrease timing error the T-Drill was assessed with a laser timer. The warm-up protocols were given by different administrators, which may have led to small inconsistencies of warm-up protocols. To control for this all protocols were given by the fewer administrators.

Summary

The warm-up is critical to pre-event preparation. The warm-up prepares the body and mind for the following event. The appropriate warm-up prepares the body to help prevent the likelihood of injury as well as prepare the participant for optimal performance. Optimal performance is the goal to every sporting endeavor. Therefore, there is a great need to determine if any component of the warm-up improves performance or even if the warm-up decreases optimal performance. More research needs to be done to answer the question if static stretching impedes agility performance, if a dynamic warm-up helps to prepare for optimum agility performance, and if static stretching dilutes the effects of dynamic stretching. To aid practitioners in making a more accurate prescription, analysis should be carried out to determine if there is a difference in effects of pre-event stretching methods on athletes of varying fitness levels.

Purpose of Research

The purpose of this study was to compare the effects of a Dynamic Stretching (DS), Static Stretching Warm-up (SS), Dynamic Stretching with Static Stretching (DS+SS) , and No Warm-Up (NWU), on agility performance as measured by the T-Drill. With the increasing evidence of the negative effects of pre-event static stretching and the increased use of dynamic stretching it is important to have scientific data to determine which method of stretching is the most appropriate to use prior to agility sports. The T-Drill was used as a dependent measure to more accurately determine the effect of static and dynamic stretching on agility performance. To determine if activity level has an

effect on static stretching or dynamic stretching the Paffenbarger Physical Activity Questionnaire was used. This was done to determine if static stretching or dynamic stretching has a greater influence on participants according to fitness level. It was hypothesized that the dynamic warm-up protocol would result in a better performance as compared to the static stretching protocol and the control group. This hypothesis is founded on the principle of specificity. Because the dynamic warm-up more closely mimics the specific movements of the agility test and is consistent with the principle of specificity. A secondary hypothesis is that the static stretching when combined with dynamic stretching protocol would decrease performance as compared to the dynamic warm-up protocol (Young & Behm, 2003). The use of the Physical Activity Questionnaire might aid professionals in making a more accurate prescription of the mode of stretching according to the participant's activity and fitness level.

Research Objectives

The main objective was to utilize different warm-up protocols: no warm-up (NWU), static stretching (SS), dynamic stretching (DS), and dynamic stretching with static stretching (DS+SS)) and evaluate the effectiveness on agility performance. The agility measurement test was the T-Drill (reliability and validity established by Pauole et al., 2000). The independent variables were the warm-up protocols: no warm-up (NWU), static stretching (SS), dynamic stretching (DS), and dynamic stretching with static stretching (DS+SS). The dependent variables were the times of the agility tests after each warm-up protocol. The lowest time of the two trials was used for analysis.

CHAPTER III

METHODS

Participants

The population studied was college-age males and females (18-28 years). There were 24 males (age, 23 ± 3 years; height, 179 ± 7 cm; weight, 82.1 ± 13.68 kg) and 10 females (age, 22 ± 2 years; height, 162 ± 10 cm; weight, 65.77 ± 9.82 kg). The participants were of varying activity levels. The participants were free from lower limb injuries (i.e., ankle or knee injuries). The participants were familiarized with static stretching, and actions utilized in the dynamic warm-ups, and the T-Drill. No participants were injured during agility testing, as they were familiar with the movement patterns and had a base level of conditioning due to their activity level at time of testing. The participants were free from lower limb injury and had no medical history of such. Maintaining this criterion for inclusion in the study was utilized to decrease the likelihood of injury during testing, as well as a decreased possibility of confounding the data.

Design

Permission was obtained prior to testing from the Utah State University Institutional Review Board. Participants were informed of the test and procedures. The protocols were performed in randomized repeated-measures, within-subject design (Hopkins, 2000). The dimensions of the markers for the T-Drill were measured and marked according to the established parameters (Pauole et al., 2000).

The Paffenbarger Physical Activity Questionnaire (Appendix C) was administered to allow grouping of the participants as low-active, moderately-active, and highly-active. The purpose of the activity level grouping was to establish if there is a greater effect of the stretching protocols depending on activity level of the participant.

Protocol improvements determined from the pilot study were (a) measurement of T-Drill with a laser timer, and (b) precise control of protocols administered, and increased sample size. Agility was chosen as the only performance outcome, due to the lack of information in the area.

Procedures

The Participants completed the Paffenbarger Physical Activity Questionnaire (Appendix C). The design was a repeated measures analysis, as the same participants completed all protocols (DS, SS, DS+SS, & NWU).

The first session was a familiarization session and completing one of the randomly assigned protocols. In the first session, the participants also completed the Paffenbarger Physical Activity Questionnaire, received instruction on the T-Drill and testing procedures. Participants then performed a dry run at 50% max effort for familiarization. The participants were then asked to jog for 2 min for a warm-up to decrease the risk of injury, which will serve as a general warm-up and the No Stretching Protocol. Then the participants performed two trials of the T-Drill from which the best of time of the two trials was used for analysis. Allocation of ordering of all protocols was randomized. On the subsequent sessions, participants performed the other remaining protocols. Participants had a 1-min rest period after the warm-up protocol and then

performed two T-Drill trials. There was also a 1-min rest period between trials.

Warm-up Protocols

A self-paced 2-min jog was conducted as a general warm-up for all protocols. The agility testing was administered 1-min after the completion of the warm-up protocols. T-Drill times were measured with an automated timer (Speedtrap II, Brower Timing Systems, Draper, UT, USA). Timing started and stopped when the participant broke a single laser light beam at the start/stop line. To control for error, the laser beam was positioned so the height above the ground approximated the height of the participant's waist.

The NWU protocol consisted of a self-paced 2-min jog. Two trials were completed, with a 1-min rest period between trials. The better of the two trials was used for analysis. The dependent measure was the time of the agility test. Time measurements were reported to the 10th of a second. The descriptions of the Dynamic and Static Stretching Protocols are defined in Table 1 and Table 2.

Instruments

T-Drill

The T-Drill was selected as measurement tool because of the dynamic nature of athletic events. These athletic events involve elements of speed, change of direction, and varying types of movement. T-Drill is carried out as follows: the participant stands at cone #1. On the command of "GO", the participant sprints 9.14 m to cone #2 and touches

the base of the cone with his right hand. Then, the participant will shuffle 4.57 m to cone #3, touching the base, then shuffling 9.14 m over to cone #4 and touch the base. After shuffling back 4.57 m to cone #2, and touching the base, the participant then back-peddles 9.14 m to the finish line where the time is recorded. A diagram of the T-Drill with its dimensions is shown in *Figure 1*.

The main objective of the T-Drill is to examine speed with change of direction. The T-Drill requires the participant to sprint, side-wards shuffle, and back-peddle, while changing direction. Pauole et al. (2000) established the T-Drill to be a reliable and valid predictor of agility leg power, and leg speed in college-age men and women. The reliability of the T-Drill is dependent on how strictly the test is conducted, the participant's level of motivation to perform the test, and methods of timing.

Paffenbarger Physical Activity Questionnaire

Dr. Ralph Paffenbarger, Jr. developed the Paffenbarger Physical Activity Questionnaire for his studies of exercise and chronic disease of Harvard and University of Pennsylvania alumni (Paffenbarger et al., 1983, 1986; Chasan-Taber et al., 2002). The questionnaire tracks work, sports and leisure activities. The scoring of the questionnaire quantifies the caloric expenditure of the activities of the participant by times per week and duration.

Activity Level Grouping

The grouping of the caloric expenditure was derived from the percentage of caloric expenditure above the basal resting metabolism. Resting Metabolic Rate (RMR)

was determined from the prediction equation established by Mifflin, et al. (1990). The equation used to calculate RMR for men is $RMR = [9.99 \times (\text{weight in lbs}) + 6.25 \times (\text{height in inches}) - 4.92 \times (\text{years})] + 5.0$. The equation used to calculate RMR for women is $RMR = [9.99 \times (\text{weight in lbs}) + 6.25 \times (\text{height in inches}) - 4.92 \times (\text{years})] - 161$. Caloric expenditure was determined from the self-report from the Paffenbarger Physical Activity Questionnaire (Appendix B). Table 3 shows the ranges for the grouping of the activity levels for analysis.

Data Analysis

Statistical analysis of the effect of the stretching protocols on agility was completed with a one-way repeated-measures ANOVA. Statistical significance was accepted at $\alpha \leq .05$. Post Hoc comparison was completed by a paired t test. Statistical significance was accepted at $\alpha \leq .05$.

Table 1

Dynamic Stretching Protocol (stretch and the intended muscle group to be affected)

Dynamic Movement	Intended Muscle Group to	
Description	be Affected	Duration
1) frontal plane leg swings	hip adductors and abductors	30 s each leg
2) sagittal plane leg swings	hip flexors and extensors	30 s for each leg
3) high knees	hip extensors	performed at a walking pace for 30 s
4) hopping in place	plantar flexors	for 20 s
5) lateral shuffles	hip adductors and abductors	performed at a walking pace for 30 s
6) flick backs, “butt kickers”	knee extensors	performed at a walking pace for 30 s
7) karaoke	hip adductors and abductors	for 20 s

Table 2

The Static Stretching Protocol (stretch and the intended muscle group to be affected)

Stretch	Intended Muscle Group to	
	be Affected	Duration
1) standing hurdler	knee extensors	for 30 s each leg
2) bent over hang	knee flexors and hip extensors	30 s
3) static lunge	hip flexors	30 s each leg
4) butterfly	hip adductors	30 s
5) figure 4	hip abductors	30 s each leg
6) Toe Drag	dorsi-flexion	30 s each leg
7) calf stretch on a step	plantar flexors	30 s

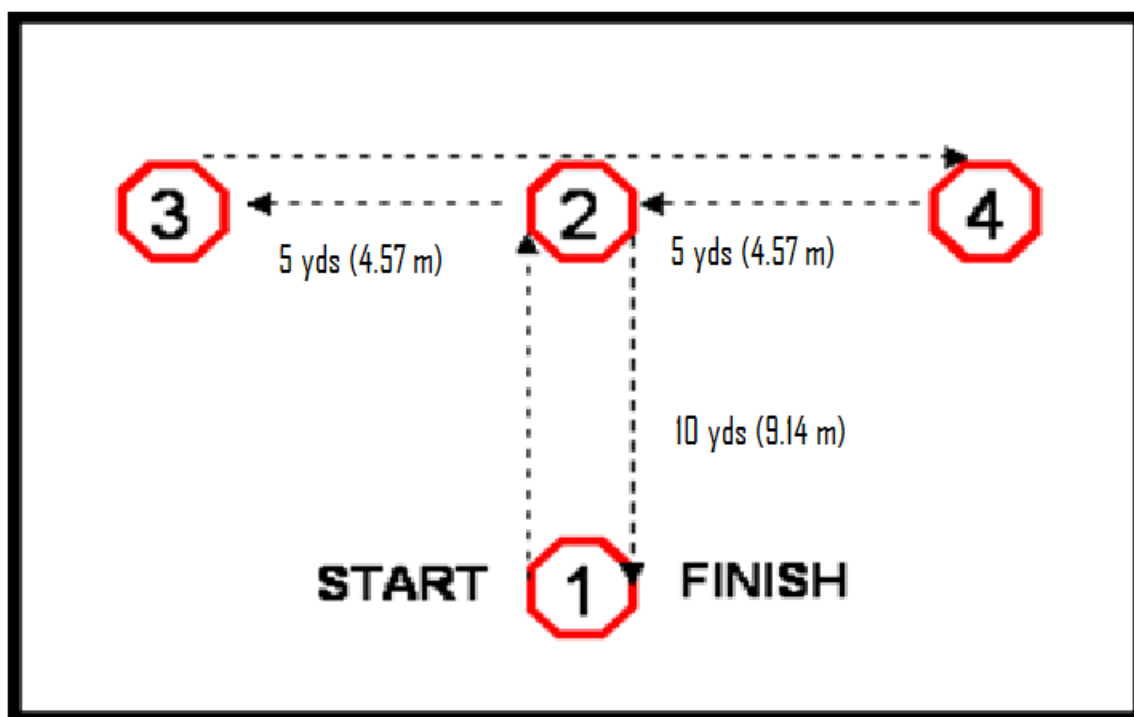


Figure 1. Diagram of the T-Drill (Semenick, 1990).

Table 3

Activity level Grouping

Activity Level	Men	Women
Low	≤ 40	≤ 35
Moderate	41-84	36-69
High	≥ 85	≥ 70

CHAPTER IV

RESULTS

Comparison of T-Drill times for differences in activity level and gender showed no significant difference ($p > 0.05$). A summary of the comparison warm-up protocols by gender is provided in Tables 8 and 9. There was no difference in the effects of the different warm-up protocols based on activity level. A summary of these findings is provided in Tables 6 and 7. Comparison of males and females showed a small difference in the DS protocol and in the DS+SS Protocol. The means were grouped for comparison of warm-up protocols. A summary of these findings is provided in Table 4. The data were pooled for a one-way repeated-measures ANOVA. A summary of the pooled data is provided in Table 5. The results of the ANOVA were: $F = 3.98$, $p = 0.009$, $F_{critical} = 2.67$. As results of the ANOVA showed a statistically significant difference, the groups were compared by a paired t -test to further analyze the specific differences between groups. The results indicated no statistically significant difference between the NWU and SS conditions (effect size = 0.40, $p = 0.06$). No significant difference was found between the NWU and DS+SS conditions (effect size = 0.01, $p = 0.48$), and the SS and DS+SS conditions (effect size = 0.40, $p = 0.06$). The results did indicate statistically significant differences between the NWU and DS conditions (effect size = 0.45, $p = 0.03$), the SS and DS conditions (effect size = 0.85, $p < 0.001$), DS and DS+SS conditions (effect size = 0.40, $p = 0.03$). The mean agility test times, in order from fastest to slowest were: (a) Dynamic Stretching (10.87 ± 1.07 s), (b) Dynamic Stretching + Static Stretching (11.41 ± 1.26 s), (c) No Warm-Up (11.42 ± 1.21 s), (d) Static Stretching (11.90 ± 1.35 s).

Table 4

Mean and Standard Deviation Results for All Warm-up Protocols

	NWU	SS	DS	DS+ SS
	$(m \pm SD)$	$(m \pm SD)$	$(m \pm SD)$	$(m \pm SD)$
Mean	11.42 s	11.90 s	10.87 s	11.41 s
<i>SD</i>	1.21 s	1.35 s	1.07 s	1.26 s

The results of the t test showed that there was no difference in the NWU and SS ($p > 0.05$), NWU and DS+SS ($p > 0.05$), SS and DS+SS ($p > 0.05$). The results of the t test showed a difference in NWU and DS ($p < 0.05$), SS and DS ($p < 0.05$), DS and DS+SS ($p < 0.05$). Mean Protocol Time in order from Fastest to Slowest: (a) Dynamic Stretching (10.87 ± 1.07 s), (b) Dynamic Stretching + Static Stretching (11.41 ± 1.26 s), (c) No Warm-Up (11.42 ± 1.21 s), (d) Static Stretching (11.90 ± 1.35 s).

Table 5

Comparison of Warm-up Protocols

Protocol Comparison	effect size	<i>p</i> value	Time difference	Faster Protocol
SS vs. NWU	0.40	0.06	0.48 s	NWU
NWU vs. DS	0.45	0.03*	0.55 s	DS
NWU vs. DS+SS	0.01	0.48	0.01 s	DS+SS
SS vs. DS	0.85	0.000*	1.03 s	DS
SS vs. DS+SS	0.40	0.06	0.50 s	DS+SS
DS+SS vs. DS	0.40	0.03*	0.54 s	DS

Note. * $p < 0.05$

Table 6

Mean and Standard Deviation for Protocols by Activity Level

Activity Level & Protocol	Mean	<i>SD</i>	<i>n</i>
High NWU	11.20 s	1.25 s	15
Medium NWU	11.64 s	1.20 s	14
Low NWU	11.52 s	1.28 s	5
High SS	11.70 s	1.33 s	15
Medium SS	12.04 s	1.40 s	14
Low SS	12.13 s	1.49 s	5
High DSS	10.69 s	1.20 s	15
Medium DSS	11.10 s	0.99 s	14
Low DSS	10.74 s	1.00 s	5
High DS+SS	11.19 s	1.31 s	15
Medium DS+SS	11.58 s	1.25 s	14
Low DS+SS	11.58 s	1.30 s	5

Table 7

Comparison of Warm-up Protocols by Activity Level

Warm-up Protocol	<i>p</i> value	<i>F</i> value
NWU	0.67	0.61
SS	0.74	0.29
DS	0.57	0.56
DS+SS	0.68	0.38

Table 8

Mean and Standard Deviation Protocols and Gender

Gender and Protocol	Mean	<i>SD</i>
Female NWU	12.03 s	0.96 s
Male NWU	11.16 s	1.23 s
Female SS	12.58 s	1.11 s
Male SS	11.62 s	1.36 s
Female DS	11.52 s	0.71 s
Male DS	10.60 s	1.09 s
Female DS+SS	12.14 s	0.89 s
Male DS+SS	11.10 s	1.28 s

Table 9

Comparison of Warm-up Protocols by Gender

Protocol	<i>p</i> value	<i>F</i> value
NWU	0.05	3.92
SS	0.05	3.89
DS	0.02	5.97
DS+SS	0.02	5.32

CHAPTER V

DISCUSSION

Agility is a movement common in many sporting events. Agility requires acceleration, deceleration, and change of direction. Agility sports require movement at high speed and against body weight. Because of this increased risk of injury, participants need to prepare the body for maximum performance possible as well as reduce the possibility for injury. Exercise professionals, and coaches need to prescribe the most effective warm-up activities that will help the body control, and efficient sport specific movement. In an attempt to prescribe the most effective mode of stretching during the warm-up, the current study evaluated agility performance as measured by the T-Drill. The warm-up protocols compared were Dynamic Stretching (DS), Static Stretching (SS), Dynamic Stretching combined with Static Stretching (DS+SS) , and No Warm-Up (NWU).

In previous research it has been recommended to use dynamic stretching as the primary method of stretching pre-event warm-up before high speed, and power activities (Little & Williams, 2004). The findings of this study agree with that recommendation for agility activities as well. This study supported the use of dynamic stretching in eliciting the greatest performance in agility movements by decreased T-Drill time. The findings of the current study are consistent with those of Fletcher and Jones (2004), and Young and Behm (2003) who determined that dynamic stretching elicits the best performance in power and high-speed activities.

The current study found static stretching to have a negative effect on agility, and acceleration (Fletcher & Jones, 2004; Nelson et al., 2005). As acceleration is a component of agility, these findings support those of Fletcher and Jones (2004) and Nelson et al. (2005). Agility also involves components of braking, and change of direction. Static stretching prior to agility activities was found to have a negative effect on agility performance.

Warm-ups, which utilize dynamic stretching, help to elicit the greatest performance in speed, power, and agility. Static stretching is shown to have a negative effect on agility performance. When dynamic stretching is combined with static stretching it was determined that static, stretching after dynamic stretching dilutes the effectiveness of the dynamic stretching. These findings are consistent with those of Young and Behm (2003) who found static stretching diluted the effectiveness of the general warm-up in jump performance.

During eccentric phase, the series elastic component lengthens, and stores elastic energy. This stored elastic energy is reused in the concentric phase of the stretch-shortening cycle when the series elastic component springs back to its original form (Potach & Chu, 2000). After static stretching the series elastic component of the musculotendinous unit is already lengthened, may impede preactivation, decrease its ability to store, and reuse as much elastic energy during the stretch-shortening cycle. The stretch-induced slack in the muscle may prevent maximal storage and reuse of elastic energy during the stretch-shortening cycle. Shorten (1987) reported that the amount of elastic energy that can be stored in the musculotendinous unit is a role of stiffness. The reduced stiffness of the musculotendinous unit may result in less elastic energy that could

be stored in the eccentric phase and used in the concentric phase. This slack would also affect the mechanical component of the stretch shortening cycle. Tendon slack requires more time to be taken in when the muscle contracts. This slack results in a less effective transfer of force from the muscle to the lever (Cornwell et al., 2001).

On the neurological component, static stretching may result in decreased neural drive from the central nervous system to the muscle (Kubo, Kanehisa, Kawakami, & Fukunaga, 2001; Nelson et al., 2005; Rosenbaum & Hennig, 1995). This could result in neurological inhibition of the neural transmission that lead to insufficient stretch reflex during the concentric phase of the stretch shortening cycle. During the acceleration, braking and change of direction phases of agility the stretch reflex may not be sufficient to generate a maximal response during the concentric phase. This would result in a decrease in performance during the concentric phase of each stretch-shortening cycle in agility movements.

The results of the present study support the idea that static stretching prior to agility, power and sprint performance has negative effect on the mechanical, and/or the neurological components of the stretch shortening cycle. Further research is necessary to identify which of these components, mechanical or neurological is responsible for the negative effect of static stretching. It is possible that a combination of both mechanisms could exist; further research is needed to determine if the detriment from pre-event static stretching is more neurological or mechanical and to what extent each has an influence on performance.

Static stretching can reduce performance in agility. It is important that exercise professionals who guide the warm-up activities are aware of the possible negative effects

of static stretching prior to agility sports. In sport performance the negative effects of static stretching could mean not reacting quick enough and getting beat on the first step which could be the difference in a game winning layup in basketball or a touchdown in football. Elite athletes must be able to perform at maximum potential because even the smallest detail could mean the difference in winning and losing. It is vital to guide the athletes in sport preparation so they are able to perform at their maximum potential with their utmost confidence.

As athletes prepare for performance, the chosen method of warm-up should best prepare the athletes for performance in the ensuing activity. The warm-up should be comprised of a general warm-up, a stretching to increase joint range of motion and sport specific activity (Young & Behm, 2002). A warm-up that utilizes static stretching makes the athlete stop and sit after the general warm-up which may result in decreased body temperature and then the athlete would move into practicing sport specific movements. A warm-up that utilized dynamic stretching would have a general warm-up, then dynamic stretches that would include movements specific to the following sport, then practicing sport specific movements. Dynamic stretching should also be prescribed according to each individual type of sporting event and the movement patterns specific to that sport. Utilizing dynamic stretching that is comparable to the movement patterns of the following sport would be more time efficient, prepare the nerves to contract the muscles in the necessary pattern of muscle activation for specific sport movements. Dynamic stretching could also decrease the time necessary for the general warm-up, which would help conserve energy for the ensuing activity.

The results of this study with the current research in this area will give exercise professionals and coaches' confidence that dynamic stretching, as part of the warm-up will aid the athletes in obtaining best performance possible.

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APPENDICES

Appendix A
Informed Consent

Date Created: February 2, 2009; Page 1 of 1
 USU IRB Approved: 02/05/2009
 Approval terminates: 02/04/2010
 Protocol Number: 2215
 IRB Password Protected per IRB Administrator



Dept. of Health, Physical Ed., and Recreation
 7000 Old Main Hill
 Logan, UT 84322-7000
 Voice: (435) 797-1506

INFORMED CONSENT

Static verses dynamic stretching effect on agility performance

Introduction/Purpose: Professor Rich Gordin, Ed.D, and graduate student Patrick Troumbley, C.S.C.S. from the department of Health, Physical Education and Recreation at Utah State University (USU) are conducting research to better understand the effectiveness of stretching warm-ups versus dynamic stretching warm-ups.

The purpose of this study is to determine the most effective method of warm-up prior to an agility activity. Agility is the ability of the body or body parts to explosively brake, change direction, and accelerate again rapidly under control. These movements also require acceleration, deceleration (braking), and rapid change of direction. The types of movement in agility are: running, side shuffling and backpedaling (running backwards). Approximately 40 college-age males and females (18-28 years) will participate in this study. The participants will be of all activity levels. The participants will be free from lower limb injuries (i.e., ankle or knee injuries).

Procedure: If you agree to participate in this study you will complete the Paffenbarger Physical Activity Questionnaire, all warm-up protocols and agility testing. A total of four 20-minute sessions will occur during the course of this study. In each session participants will complete one of the warm-up protocols (Control of jogging of 2 minutes with no stretch, 2 minute jog with static stretching, 2 minute jog with dynamic stretching, and 2 minute jog with dynamic stretching and dynamic stretching), and agility testing. The findings for this study will only be used for academic purposes.

New Findings: During the course of this research study, you will be informed of any significant new findings (either good or bad), such as changes in the risks or benefits resulting from participation in the research, or new alternatives to participation that might cause you to change your mind about continuing in the study. If new information is obtained that is relevant or useful to you, or if the procedures and/or methods change at any time throughout this study, your consent to continue participating in this study will be obtained again.

Risks: Participation in this research study may involve some added risks or discomforts. These include falling, rolled ankle, minor bumps. These risks will be no greater than at any other low impact sporting activity. While performing the warm-ups and agility testing, adequate safety precautions will be provided. It should be noted that as with any study, there might be some unforeseen risks that could occur that are not described above, but researchers will take every precaution to minimize these risks.

Benefits: There may not be any direct benefit from participating in this study; however, the researchers hope to identify which method of warm-up results in greater agility performance. This information may be a benefit to coaches, trainers, athletes.

Explanation & Offer to Answer Questions: Patrick Troumbley has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may call Professor Gordin at (435) 797-1506

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 7000 Old Main Hill
 Logan, UT 84322-7000
 Voice: (435) 797-1506

INFORMED CONSENT

Static verses dynamic stretching effect on agility performance

Extra Costs: There will be no extra costs to you for your participation in this study.

Payment/Compensation: You will not receive any payment as compensation for your participation in this study.

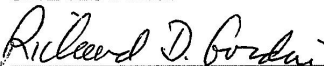
Voluntary Nature of Participation & Right to Withdraw without Consequence: Participation in the study is voluntary; you may withdraw at anytime without consequence. If you feel you would rather not continue participation, you may discontinue at any time without penalty or consequence. Please inform Patrick of your decision to withdraw.

Confidential: Research records will be kept confidential, consistent with federal and state regulations. Only the investigator will have access to the data which will be kept in a locked file cabinet in a locked Huntsman Cancer Hospital, Room 2125, Clinic room C. Access to the data will only be accessible to Richard Gordin and Patrick Troumbley. Personal, identifiable information will be kept long enough to analyze the data. As soon as the data is analyzed, identifiable information will be destroyed, on or about July 15, 2009.

IRB Approval Statement: The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any pertinent questions or concerns about your rights or a research-related injury, you may contact the IRB Administrator at (435) 797-0567. If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

Copy of Consent: You have been two copies of this Informed Consent. Please sign both copies and keep one copy for your files.

Investigator Statement: "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."


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Signature of Participant: By signing below I agree to participate.

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INFORMED CONSENT

Static verses dynamic stretching effect on agility performance

Participant's signature

Date

Name _____ Date _____

1. How many stairs did you climb up on an average day during the past year?

2. How many city blocks or their equivalent did you walk on an average day during the past year?

3. List any sports, leisure, or recreational activities you have participated in on a regular basis during the past year. Enter the average number of times per week you took part in these activities and the average duration of these sessions. Include only time you were physically active (that is, actual playing or activity time).

[illegible]

Paffenbarger Physical Activity
Questionnaire
Scoring Worksheet

1. Energy expenditure associated with stair climbing

_____ stairs climbed/day * 7 days/week = _____ stairs climbed/wk

_____ stairs climbed/week * 8 kcal/20 stairs =

_____ kcal energy expended/week stair climbing

2. Energy expenditure associated with walking

_____ blocks walked/day * 7 days/week = _____ blocks walked/week

_____ blocks walked/week * 8 kcal/block =

_____ kcal energy expended/week walking

3. Energy expenditure associated with light sport or recreational activities

_____ total minutes of light sport/recreational activities/week

* 5 kcal/minute =

_____ kcal expended/week in light sport/recreational activities

4. Energy expenditure associated with vigorous sport or recreational activities

_____ total minutes of vigorous sport/recreational

activities/week * 10 kcal/minute =

_____ kcal expended/week vigorous sport/recreational activities

5. Total sport, leisure, and recreational energy expenditure per week

kcal/wk stair climbing _____

kcal/wk walking _____

kcal/wk light sport/recreational _____

kcal/wk vigorous sport/recreational _____

Total kcal/wk expended _____

Appendix C

Pilot Study

The pilot study was conducted as a class project in PEP 6540; Wellness Programming, instructed by Dr. Eadric Bressel.

Results of the Pilot Study

All participants completed the protocols as allocated and scheduled. Results of the analysis showed no statistical significance ($p > .05$) was found between the means of the protocols.

Table 10

Results of the Pilot Study.

	NWU	DWU +SS	DWU
Mean	10.963	10.68	10.583
SD	0.2802	0.2523	0.6061

The purpose of the pilot study was to compare the effects of DWU, DWU+SS, and NWU on a measure of agility performance. The results of the pilot study indicated that there was no statistical difference between the protocols, which is contrary to the findings of Young and Behm (2003). While the dynamic warm-up produced the lowest mean time in T-Drill, there were no real differences found in the measured warm-up protocols. However, these results do mirror the findings of McMillian (2006) who

showed that a dynamic warm-up protocol enhanced performance measures of agility relative to SS and NWU. This may also be due to the chronic practice of the dynamic warm-up as opposed to the single bout prior to testing. The findings of the pilot study contrast with Bishop's review of literature, which indicates that a dynamic warm-up of moderate intensity significantly improves short-term muscular power and agility performance.

Conclusions of the Pilot Study

Due to the lack of participants, these data provide limited support for recommendation of use of the dynamic warm-up over the dynamic warm-up with the static stretching or no warm-up prior to participation in short duration explosive athletic movements.

Confounding Variables of the Pilot Study

The lack of significant improvement in terms of agility performance within this study may be attributed to several confounding variables. The small sample size is the main factor attributed to not finding a statistically significant difference in the means of the warm-up protocols. Another factor is that the participants were not reminded of the importance of maximal effort nor was there any verbal encouragement during the testing procedure. Although maximal effort was discussed in the familiarization process, failure to provide a reminder prior to testing may have influenced the motivation of the participants and consequently the measured performance times. Verbal encouragement and reminder of the importance of maximal effort was utilized in testing. In the pilot study the speed of the T-Drill was assessed with a stopwatch. To decrease timing error

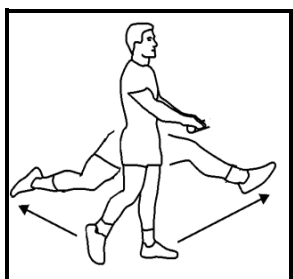
the T-Drill was assessed with a laser timer. The warm-up protocols were given by different administrators, which may have led to small inconsistencies of warm-up protocols. To control for this all protocols were given by the fewer administrators.

Appendix D

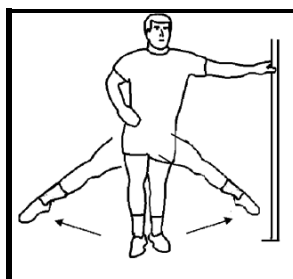
Dynamic and Static Stretching Protocol Pictures

Figure 2.

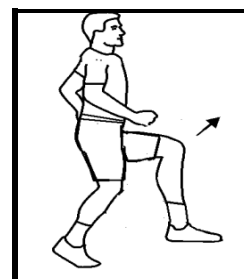
Dynamic Stretching Protocol Pictures



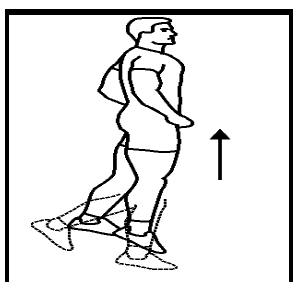
1) frontal plane leg swings



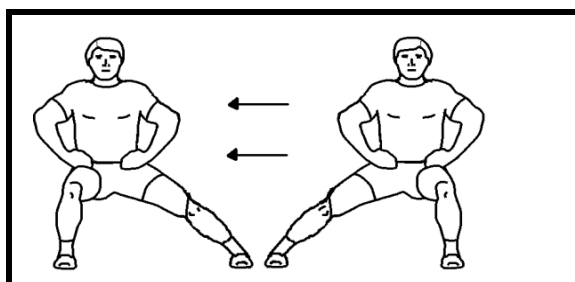
2) sagittal plane leg swings



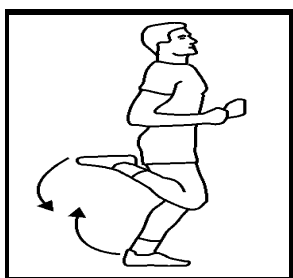
3) high knees



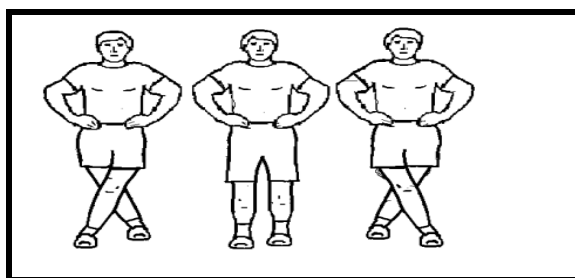
4) hopping in place



5) lateral shuffles



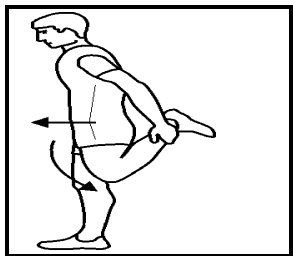
6) flick backs, "butt kickers"



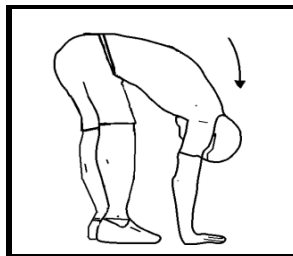
7) karaoke

Figure 3.

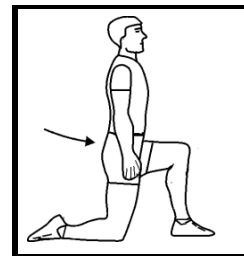
Static Stretching protocol Pictures



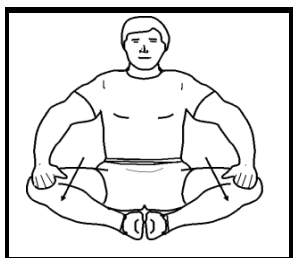
1) standing hurdler



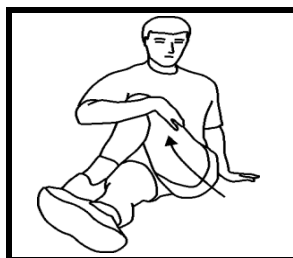
2) bent over hang



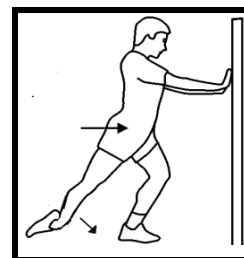
3) static lunge



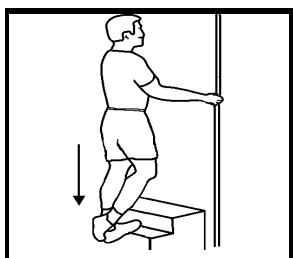
4) butterfly



5) figure 4



6) Toe Drag



7) calf stretch on a step