THE EFFECTS OF STATIC AND DYNAMIC STRETCHING PROTOCOLS ON A 30-SECOND ANAEROBIC BICYCLE TEST

A THESIS

Submitted to the Faculty of the School of Graduate Studies and Research of California University of Pennsylvania in partial fulfillment of the requirements for the degree of Master of Science

by

Tiffany M. Estes

Research Adviser, Dr. Bruce Barnhart
California, Pennsylvania
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CALIFORNIA UNIVERSITY OF PENNSYLVANIA

CALIFORNIA, PA

THESIS APPROVAL

Graduate Athletic Training Education

We hereby approve the Thesis of

Tiffany M. Estes
Candidate for the degree of Master of Science

<table>
<thead>
<tr>
<th>Date</th>
<th>Faculty</th>
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<tbody>
<tr>
<td>4-30-08</td>
<td>Bruce D. Barnhart, EdD, ATC, PTA - Research Advisor</td>
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<tr>
<td>4-30-08</td>
<td>Benjamin Reuter, PhD, CSCS, *D, ATC - Committee Member</td>
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<tr>
<td>4-30-08</td>
<td>Robert H. Kane, Jr., Ed.D, ATC, PT - Committee Member</td>
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I would like to take this opportunity to thank the many people who made this thesis a success. First and foremost I would like to thank my parents for always believing in me and for giving me every opportunity they could to help me reach my goals. Specifically, my mom and her co-worker, Emma, for helping me get the computer functioning so I was able to collect data, and my dad for lending me his laptop, which was a tremendous help. I want to thank my brother, Derek, for being the best brother a sister could have. I also want to thank Josh, my fiancé for all his support and help throughout this entire process.

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INTRODUCTION

There has been much debate in recent years about which type of warm-up and stretching routine is best for optimal athletic performance. The movement of the body is affected by several energy systems, and it is important to know what makes the body function optimally. High speed and maximum intensity bouts of exercise are required in many sports and activities. The question remains, which warm-up routine is most beneficial for maximal exercise lasting 30 seconds?

Warm-up routines play a large role in muscular performance during sports. Stretching has several physiological effects on the body. Research has shown that differences in warm-up routines affect muscle function, flexibility, and chance of injury. An active warm-up is believed to increase the body core temperature, heart rate, and blood flow. It also decreases the viscosity of connective tissue, increasing muscular performance and enhancing psychological performance. Although there are many variations, the most common routines involve a low-intensity aerobic exercise followed by static stretching. Recent research suggests that a flexibility-
centered warm-up may not be the most effective way to prepare the athlete for movement or to develop long-term soft tissue adaptations.\textsuperscript{11} Therefore, a dynamic warm-up has been advocated as a pre-exercise routine.\textsuperscript{1-6, 11, 14} Other protocols used are proprioceptive neuromuscular facilitation and ballistic stretching.\textsuperscript{8-10}

Flexibility is an important component for activities of daily living and for sports, particularly ones that call for increased mobility. Although it has been shown that a dynamic warm-up is more beneficial for performance, a lack of flexibility may increase the chance of injury.\textsuperscript{18} Arguments are ongoing as to which warm-up protocol is more beneficial for athletes engaging in powerful anaerobic activities.

Power, jumping performance, and speed are imperative in today’s competitive sports world. Recent research has suggested that utilizing a dynamic warm-up routine instead of static stretching increases power\textsuperscript{1, 2}, jumping performance\textsuperscript{3, 4}, and acceleration/speed.\textsuperscript{5} Some studies have found a decrease in mean running speed\textsuperscript{6} or no change at all\textsuperscript{5} following a static stretching protocol.

There are many tests available to measure the body’s energy systems. Tests that tax the anaerobic glycolytic system usually last from 20-50 seconds.\textsuperscript{23} The formation of
ATP, mainly from glycolysis, takes place between 20 and 35 seconds of maximal exercise. Different tests have been established to anaerobically test the system: 30-second Wingate test, DeBruyn-Prevost constant-load test, and sport specific tests. The 30-second Wingate test has been shown to be the most reliable and valid in comparison to the other tests. Gullstrand et al used the Wingate test to assess ice hockey and soccer players. The results were similar for both groups. Skating and running times were faster when the subjects produced more mean power during the test. This demonstrates that anaerobic power is beneficial for fast, powerful sport-specific activities.

Many varieties of warm-up and stretching routines exist. Although some coaches favor some over others, the chosen routine is not always the most beneficial for athletic performance. Athletic trainers should be aware of different warm-up routines and what is in the best interest of the athlete. This study examined whether maximal exercise lasting 30 seconds, using an anaerobic bicycle test, based on the Wingate test, was improved following a dynamic stretching protocol in comparison to a static stretching protocol and no stretching.
METHODS

This section includes the following subsections: Research Design, Subjects, Instruments, Procedures, Hypothesis, and Data Analysis.

Research Design

This study was a quasi-experimental, within subjects design. All subjects were volunteers. The independent variable was the stretching routine (dynamic stretching, static stretching, and no stretching). The dependent variable was the measure of anaerobic performance. A strength of this study was that it was a within subject design; therefore, each subject was serving as their own control. Additionally, all subjects were male athletes, so they were fit and active. Limitations of this study were that it was limited to Division II athletes, and that the same person was serving as the researcher and the data collector.
Subjects

The subjects in the study consisted of Division II male athletes (N = 15) from California University of Pennsylvania. All subjects were between the ages of 18 and 25 and had no injuries for the last 6 months to any part of the lower extremity. The subjects were all volunteers. Each subject was instructed to read and sign an Informed Consent Form (Appendix C1) which included the purpose of the study and the right to remove himself/herself from the study at any time without penalty. No names were included in the study.

Instruments

The testing instrument used in this study was a 30-second anaerobic bicycle test, based on the 30-second Wingate test, using the Lode Excalibur Sport ergometer. The 30-second anaerobic bicycle test was used to measure power output of the subject. During the test, each subject pedaled as fast as possible and against resistance for 30 seconds. The resistance load was 0.075 kilogram per kilogram of body weight. It was applied to the ergometer after four seconds of maximal pedaling by the subject.
Once the weight was added, the 30 second test begins. To determine the amount of resistance, each subject was weighed prior to any testing.\(^{19}\) Peak power was measured within the first 5 seconds, whereas mean power was calculated from 0 to 30 seconds. The final 5 seconds is known as end power.\(^{19}\) Peak power is defined as the highest mechanical power achieved during any stage of the test. Mean power is the degree of anaerobic glycolysis, or endurance in the working muscles and is expressed in kilograms of body weight.\(^{19-22}\) The Wingate test is a valid and reliable measure for anaerobic activity.\(^{19,22}\)

The tests were performed on a Lode Excalibur Sport ergometer.\(^{23}\) This ergometer can withhold workloads from 8-2500 watts. Since all subjects had different heights, the handlebar and seat was easily adjusted. The positioning of the handlebar and seat were documented; therefore, the same positioning was set during all testing sessions. The resistance was kept constant throughout the test. The amount of resistance was determined depending on the subject’s body weight. Since the subjects were pedaling at their maximum, toe clips were used to ensure that their feet remained on the pedals and no injuries occurred due to slippage. The Lode Excalibur Sport ergometer was used to measure peak power and mean power.\(^{19, 23}\)
Procedures

This study was approved by the California University of Pennsylvania Institutional Review Board (IRB) (Appendix C2). The researcher acquired permission to use California University of Pennsylvania (NCAA Division II) athletes from the California University of Pennsylvania men’s soccer coach (see letter, Appendix C3). Volunteer subjects were gathered, all of whom had not suffered from a lower extremity injury in the past 6 months. Before testing of the subjects, the researcher met with the subjects and explained the concept of the study. During the meeting, the Informed Consent Form (Appendix C1) was distributed explaining the procedure, the need for the study, and the risks involved. A demographic sheet was also distributed to each subject asking for gender, height, weight, age, and availability for testing (Appendix C4). The researcher also explained that the subject with the highest power output would receive a gift card at the conclusion of all testing and data collection.

The researcher explained to each subject that he would be individually tested three different times on nonconsecutive days. There must be at least one day, but
not more than four days, in between testing sessions. Time slots were agreed upon by the researcher and the subject, so each subject was tested individually. The subject was not aware of what stretching protocol he would perform until his testing time. The protocol for each day was randomly assigned. Each subject had three papers with a specific stretching routine printed on it. These papers were kept in the subject’s individual file. The subject picked a paper out of a bag each testing day, and once a paper was drawn, it was discarded. The subject was assigned static stretching, dynamic stretching, or no stretching based on what was written on the paper.

On testing day, each subject was weighed on a scale, and then performed the selected stretching protocol. Following stretching and a one minute rest, a five minute warm-up was performed on the cycle ergometer. The warm-up in the ergometer continued straight into the 30-second test.

The static stretching protocol (Appendix C5) consisted of a quadriceps stretch, abductor stretch, hip flexor stretch, adductor stretch, hamstring stretch, gluteal stretch, and the gastrocnemious/soleus stretch. Each stretch was held for 20 seconds bilaterally.
The dynamic stretching protocol (Appendix C6) consisted of high knees (gluteals and hamstrings), drop lunges (gluteals and hip flexors), flick backs (quadriceps and hip flexors), lateral shuffles (adductors and abductors), and heel to toe walks (gastrocnemius and soleus).\textsuperscript{1, 24}

The researcher had a tape recording to inform the subject when to switch stretches, to ensure that each subject was stretching for the same duration and that rest periods were consistent. The same tape recording was used for the entire session from the beginning of the warm-up to the end of test. Subjects in the control group (no stretching) rested during the time it took to complete each stretching protocol. Each subject had a one minute rest period following the stretching protocol to prepare for the warm-up and test on the ergometer. During this rest period it was explained again that the subject must pedal as fast as possible from start to finish of the anaerobic bicycle test.

After the one minute rest, the subject began the five-minute warm-up on the ergometer. This was completed at a comfortable, consistent pace. The warm-up went immediately into the test, which began on the command “go” and was pre-recorded on the cassette tape. The subject began to pedal
as fast as he could with light resistance. After 4 seconds, the resistance of 0.075 kilograms per kilograms of body weight was added to the ergometer. After the load was applied, the 30-second test began. Verbal encouragement was pre-recorded on the cassette tape. The command “stop” was recorded on the tape to instruct the subject when the test was finished. Immediately following the “stop” command, “begin cool-down now” was recorded. All subjects performed a cool-down following the test. It consisted of two minutes of pedaling with light resistance on the cycle ergometer. The same procedure was followed for each subject on his appointed day until each had performed all three stretching protocols.

Hypothesis

The following hypothesis is based on the literature reviewed during the development of this study.

1.) Mean power output during a 30-second anaerobic bicycle test will be greater following a dynamic stretching protocol than it will be following a static stretching protocol or no stretching.
Data Analysis

All data was analyzed using the SPSS statistical software package version 14.0, with an alpha level of 0.05. For hypothesis one, an analysis of variance was used to analyze the results generated using the stretching routine as the independent variable, and the measure of anaerobic performance as the dependent variable.
RESULTS

The purpose of this study was to examine the differences between a static stretching protocol, a dynamic stretching protocol, and no stretching protocol and their effects on mean power output during a 30-second anaerobic bicycle test. The results are divided into three sections: demographic data, hypothesis testing, and additional findings.

Demographic Data

A total of fifteen subjects (N = 15) completed this study. The subjects were volunteer male Division II athletes from California University of Pennsylvania. The demographics of the subjects were as follows: The mean age of the subjects was 21.13 years (± 2.07). The mean height of the subjects was 177.04 cm (± 5.40). The average weight of the subjects was 78.59 kg (± 5.65). This information can be seen in Table 1.
Table 1. Demographic Information

<table>
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<tr>
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<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
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<td>Weight (kg)</td>
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<td>75.6</td>
<td>87.80</td>
<td>78.59</td>
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<td>Height (cm)</td>
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<td>170.0</td>
<td>185.42</td>
<td>177.04</td>
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Hypothesis Testing

The following hypothesis was tested in this study. All tests of statistical significance used an alpha level of 0.05.

Hypothesis 1: Mean power output will be greater following a dynamic stretching warm-up than it will be following a static stretching warm-up and no warm-up.

Conclusion: Mean power was calculated under three test conditions (no stretching, dynamic stretching, and static stretching). Data was analyzed using a one-way, repeated measures analysis of variance (ANOVA). Data showed significant differences depending upon the test condition, with dynamic stretching resulting in the highest mean power and no stretching resulting in the lowest. Significant findings were revealed ($F(1,14) = 6.352, P = 0.005$). Results are shown in Table 2.
Table 2. Mean Power Output in Watts during a 30-second anaerobic bicycle test under three stretching conditions

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<td>551.13</td>
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<td>564.80</td>
<td>81.949</td>
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Additional Findings

After testing the hypothesis, additional statistical analyses were conducted to determine if any relationships existed among peak power, rate to fatigue, total work, and minimum power and warm-up protocol.

Peak power was calculated under three test conditions (dynamic stretching, static stretching, and no stretching). No significant findings were found using a one-way, repeated measures analysis of variance (ANOVA). Differences were found between stretching groups, but these differences were not statistically significant ($F(1,14) = 1.130$, $P = 0.340$). Results are shown in Table 3.

Table 3. Peak Power Output in Watts during a 30-second anaerobic bicycle test under three stretching conditions
Rate to fatigue was calculated under three test conditions (dynamic stretching, static stretching, and no stretching). No significant findings resulted using a one-way, repeated measures analysis of variance (ANOVA). Differences were found between stretching groups, but these differences were not statistically significant (F(1,14) = 1.129, P = 0.338). Results are shown in Table 4.

Table 4. Rate to Fatigue in Watts/second during a 30-second anaerobic bicycle test under three stretching conditions

<table>
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</thead>
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<tr>
<td>No Stretching</td>
<td>15</td>
<td>18.97</td>
<td>6.319</td>
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<tr>
<td>Dynamic Stretching</td>
<td>15</td>
<td>21.01</td>
<td>8.947</td>
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<tr>
<td>Static Stretching</td>
<td>15</td>
<td>18.47</td>
<td>6.048</td>
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Total work was calculated under three test conditions (dynamic stretching, static stretching, and no stretching). No significant findings resulted using a one-way, repeated measures analysis of variance (ANOVA). Differences were found between stretching groups, but these differences were not statistically significant (F(1,14) = 0.376, P = 0.690). Results are shown in Table 5.
Table 5. Total Work in Joules during a 30-second anaerobic bicycle test under three stretching conditions

<table>
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<th>Standard Deviation</th>
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<tr>
<td>No Stretching</td>
<td>15</td>
<td>16662.67</td>
<td>2516.495</td>
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<tr>
<td>Dynamic Stretching</td>
<td>15</td>
<td>17081.33</td>
<td>2886.332</td>
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<tr>
<td>Static Stretching</td>
<td>15</td>
<td>16887.33</td>
<td>2473.253</td>
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</table>

Minimum power was calculated under three test conditions (dynamic stretching, static stretching, and no stretching). No significant findings resulted using a one-way, repeated measures analysis of variance (ANOVA). Differences were found between stretching groups, but these differences were not statistically significant ($F(1,14) = 0.358, P = 0.702$). Results are shown in Table 6.

Table 6. Minimum Power Output in Watts during a 30-second anaerobic bicycle test under three stretching conditions

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<tr>
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<td>369.13</td>
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<tr>
<td>Static Stretching</td>
<td>15</td>
<td>357.33</td>
<td>94.115</td>
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Some differences in means of the various measurements were seen, but only changes in mean power between test conditions were significant. Although the changes in peak power, rate to fatigue, and minimum power are not significant, a difference can be seen between the three test conditions. Results are shown in Table 7. Italicized
numbers are those that have shown a difference over the others in accordance with performance during a 30-second anaerobic bicycle test.

Table 7. Mean outputs for each variable during a 30-second anaerobic bicycle test under three stretching conditions

<table>
<thead>
<tr>
<th></th>
<th>Mean Power*</th>
<th>Peak Power*</th>
<th>Rate to Fatigue#</th>
<th>Total Work§</th>
<th>Minimum Power*</th>
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<td>18.97</td>
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<td>DS</td>
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<td>SS</td>
<td>564.80</td>
<td>851.27</td>
<td>18.47</td>
<td>16887.33</td>
<td>357.33</td>
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</tbody>
</table>

* Watts  
# Watts/second  
§ Joules
DISCUSSION

The following discussion is divided into three subsections: Discussion of Results, Conclusions, and Recommendations.

Discussion of Results

The purpose of the study was to examine the differences between a static stretching protocol, a dynamic stretching protocol, and no stretching protocol and their effects on mean power during a 30-second anaerobic bicycle test.

Much debate has arisen recently about which stretching protocol is best prior to physical activity. The most common routine involves a low-intensity aerobic exercise followed by static stretching.\textsuperscript{1-5,7,8,11,14} However, recent research has suggested that this may not be the best way for an athlete to prepare for athletic activity.\textsuperscript{11} Therefore, a dynamic warm-up has been suggested as a pre-exercise routine.\textsuperscript{1-6,11,14,17} The aim of this study was to
compare the effects of no stretching, dynamic stretching, and static stretching on power output during a 30-second anaerobic bicycle test.

It was initially hypothesized that mean power output would be higher following a dynamic stretching protocol higher than after a static stretching and no stretching protocol during a 30-second anaerobic bicycle test. The test was performed on a Lode Excalibur Sport ergometer. As a whole, dynamic stretching resulted in higher outcomes for peak power, rate to fatigue, total work, and minimum power, although mean power was the only significant result. Consistent with other findings, a dynamic warm-up has been found most effective for a pre-exercise routine.

The results of this study were similar to Yamaguchi et al., Little et al., and McMillian et al. These studies found significant differences between static stretching, dynamic stretching, and no stretching groups. The study by Yamaguchi et al. suggested that static stretching for thirty seconds neither improves nor reduces muscular performance and that dynamic stretching enhances muscular performance. Little et al. found a dynamic warm-up to be most effective at the 10 and 20 meter sprint times when compared to static stretching and no stretching, but not for vertical jump. Their conclusion was that static stretching does not appear
to be detrimental to performance; however, a dynamic warm-up was the most effective preparation for the subjects.

With regards to anaerobic activity and power output, no studies have been performed to examine the effects of stretching conditions. Other studies\(^2,6\) have taxed the anaerobic glycolic system and looked at performance. Little et al\(^5\) found that static stretching preceding activity inhibits performance.

Conclusions

Based on the results of this study, there is a difference of mean power output during a 30-second anaerobic bicycle test, dependant upon stretching condition. Each subject completed a 30-second anaerobic bicycle test three times, once under each stretching condition, on non-consecutive days. Results showed that mean power output was significantly increased following a dynamic stretching protocol. Other differences were seen (peak power, rate to fatigue, total work, and minimum power) however, were not significant. This information is key when related to athletic performance. A dynamic stretching protocol increases power output and performance during anaerobic activities. In soccer, football,
lacrosse, field hockey, and other sports, quick bursts of power are necessity. With this information it is important to know that a dynamic stretching protocol before anaerobic activity has positive effects on performance and should be implemented as a pre-workout activity.

Recommendations

There is a difference in performance based on stretching protocol. It is important for the coaches and Certified Athletic Trainers to be aware of the positive effects of a dynamic stretching protocol. Although not all results are significant, sometimes all it takes to win the competition is a fraction of a second. Therefore, it is essential to be educated about which stretching protocol is best for athletic performance.

A recommendation for further research is to test more subjects, and testing a wider variety of sports and skill levels would be beneficial. If athletes from other sports test similarly, it would be beneficial for them to incorporate a dynamic stretching protocol into their warm-up routines.
Another recommendation is to have each subject test twice under each stretching protocol. This will decrease the learning effect and give more accurate results.
REFERENCES


9. Marek, SM; Cramer, JT; Fincher, AL; Massey, LL; Dangelmaier, SM; Purkayastha, S; Fitz, KA; Culberston, JY. Acute effects of static and propioceptive neuromuscular facilitation stretching on muscle strength and power output. *Journal of Athletic Training*, 2005;40(2):94-103.


APPENDIX A

Review of Literature
There has been much debate in recent years about what type of warm-up and stretching routine is best for optimal athletic performance. A great deal goes into movement of the body. It is important to know what makes it function optimally. High speed and maximum intensity bouts of exercise are required in many sports and activities. Which warm-up routine is most beneficial for maximal speed in exercises lasting 30 seconds? This literature review will examine common pre-exercise warm-ups, and their effect on anaerobic exercise.

The topics that will be discussed include 1) Physiology of Muscle Contraction, 2) Stretching Techniques, 3) The physiological effects of stretching, and 4) Measurements. A summary of the literature is included at the end of the literature review as well.

Physiology of Muscle Contraction

The human body is a complex structure and a great deal is involved in movement of the body. Adaptations are usually made when a daily routine is continued over a period of time. Much goes into movement of the body and
the different energy systems are utilized depending on the duration and intensity of the exercise.

Skeletal muscle is one structure of the human body that is required for movement.\textsuperscript{1,2} This muscle type is controlled voluntarily. There are over 600 skeletal muscles in the body\textsuperscript{1} and they account for about 40 percent of an individual's body weight.\textsuperscript{2,3} The outer covering of connective tissue is the epimysium, which holds the entire muscle together. Under the epimysium there are small bundles of fibers, called fasciculi, which are wrapped in a connective sheath, the perimysium. Deeper into the muscle are the individual muscle cells, known as muscle fibers, which are held together by the endomysium.\textsuperscript{1,4} Muscle fibers, or cells, are small, and can only be seen through a microscope. The number of fibers in different muscles ranges from 10,000 (e.g. First lumbrical muscle) to more than a million (e.g. gastrocnemious muscle).\textsuperscript{1}

Human skeletal muscle has three types of fibers, each of which have different speeds of contraction and strength. Slow twitch (ST) fibers are slow contracting, slow fatiguing fibers and are classified as type I.\textsuperscript{1-4} Fast twitch (FT) fibers are fast contracting, fast fatiguing fibers classified as type II. FT fibers are categorized into type IIa and type IIx fibers.\textsuperscript{2}
Slow twitch fibers have a slow contractile speed and high levels of aerobic endurance. The fatigue rate for ST fibers is very slow compared to other fiber types. Therefore, these fibers are recruited for prolonged, low-intensity activity, such as distance running, and when muscle force requirements are low, as during walking.\textsuperscript{1,2}

Fast twitch fibers are the opposite of slow twitch fibers. They are classified as type II and further divided into type IIa and type IIx. All FT fibers have a fast contractile speed\textsuperscript{1} and fatigue rate, and therefore, are recruited with anaerobic activity (without oxygen). Fast twitch fibers have a small number of mitochondria and high amounts of ATPase activity. High ATPase activity results in a high speed of muscle shortening or contracting. For quick, powerful contractions of the muscles there is a high amount of ATPase activity in the cells. Small numbers of mitochondria in the muscle cells means there is less capacity to produce ATP aerobically. Therefore, fast twitch fibers do not need oxygen to produce ATP.\textsuperscript{2} Type IIa fibers are used during shorter, higher intensity endurance events, such as the mile run or 400 meter swim. Type IIx fibers are used predominantly in highly explosive events such as the 100 meter dash and 50 meter sprint swim.\textsuperscript{1} Both type IIa and type IIx have a high glycolytic capacity.\textsuperscript{1,2}
While type IIa is a combination of the aerobic and anaerobic energy systems, type IIx fibers are predominantly utilized by the anaerobic energy systems.

Most skeletal muscles contain all three types of fibers; however, the percentages of each vary from person to person. A person will have similar fibers types in their upper and lower extremities. For example, if an individual with a predominance of ST fibers in their arm muscles, the percentage will be similar in the legs. The same goes for FT fibers.¹ A connection has been shown in athletes. Sprinters generally possess a high percentage of fast twitch fibers, while endurance, long distance runners possess increased percentages of slow twitch fibers.²

Most FT fibers produce greater force than ST fibers for one main reason: their diameter.¹ FT fibers have a tendency to be larger than ST fibers; therefore can generate more force.¹ Neural stimulation affects the amount of force a muscle exerts upon contraction. Initially, when a stimulus is applied, summation occurs, which is the addition of successive twitches. When the frequency of the stimulation is increased, the individual contractions are blended together, which is known as a tetanic contraction. This contraction continues until the stimulation is stopped or muscle fatigue. A tetanic contraction results in a
smooth and coordinated muscle contraction. These contractions occur during normal body movements.

Within the skeletal muscle fibers are muscle spindles. Muscle spindles are important mechanoreceptors for proprioception; they trigger reflexive muscle action when the length of muscle is changed. Mechanoreceptors are those that respond to mechanical forces such as pressure, tough, vibrations, or stretch. Muscle spindles respond to the speed of the stretch as well. The faster the stretch is conducted the faster the muscle spindles react. The fibers inside the capsule, which provide sensory information, are called intrafusal fibers. When a muscle is stretched, the intrafusal fibers stretch. They contain little actin and myosin filaments, which are thin and thick protein filaments, respectively. Actin and myosin are responsible for muscle action. The spindles outside the connective tissue capsule are referred to as extrafusal fibers. Extrafusal fibers shorten when a muscle contracts, therefore their firing rate for impulses decreases. Muscle fibers run parallel with muscle spindles. Muscle spindles contain two types of sensory nerve endings, primary and secondary. The primary endings are responsive to dynamic changes in muscle length while secondary endings solely provide the central nervous system with information about
static muscle length. Most importantly, the muscle spindle assists in normal muscle action because of their ability to detect and cause the central nervous system to respond to changes in muscle length.\textsuperscript{1,2}

Another key mechanoreceptor of skeletal muscle is the Golgi tendon organ (GTO). GTO’s are most sensitive to tension forces generated by muscle contraction.\textsuperscript{1,2} Approximately 5 to 25 muscle fibers are usually connected with each Golgi tendon organ. While muscle spindles monitor the length of a muscle, Golgi tendon organs are sensitive to tension in the muscle-tendon complex and operate like a strain gauge, a device that senses change in tension.\textsuperscript{1} They are inhibitory in nature, providing a protective function to reduce the risk for injury\textsuperscript{1} by ‘shutting off’ the agonist contraction and stimulating the antagonist muscle.\textsuperscript{2} This process is known as autogenic inhibition. GTO’s inhibits muscular contraction if the tendon fibers are overstretched and are exerting more force than the bones and connective tissue can handle.\textsuperscript{1}

Adenosine triphosphate, ATP, is the primary energy for movement of the human body.\textsuperscript{1,2,4} ATP is utilized in three different energy systems: the ATP-PCr system, the glycolytic system, and the oxidative system.\textsuperscript{1,4}
In muscular activities that require near-maximal force production, such as sprint running and swimming, much of the energy needs are met by the ATP-phosphocreatine (PCr) system and the anaerobic breakdown of muscle glycogen (glycolysis). The third system, the oxidative system requires oxygen (aerobic) and is not recruited until after the first two to three minutes of exercise. All muscles have all three types of cells; however the energy system that is used is based upon the activity.

The ATP-PCr system is most predominant during the first 6 seconds of maximal effort exercise. The process is anaerobic because oxygen is not required. Activities that utilize the ATP-PCr system are the shot put, vertical and high jump, and the first seconds of a sprint. For longer activities other energy systems must be used. This is the simplest and quickest way of producing movement.

The anaerobic glycolytic system is in use during 30 second bouts of activity. Ultimately anaerobic glycolysis produces pyruvic acid or is transported into mitochondria, which is then converted to lactic acid. The accumulation of lactic acid in the muscle slows the rate at which glycogen can be broken down and may interfere with the mechanism involved in muscle contraction. The glycolytic system may inhibit muscle contractions because of the
buildup of lactic acid, however, it is a major contributor of energy during the first 30 seconds of maximal, high intensity exercise.\textsuperscript{1,2,4}

The oxidative system involves the use of oxygen and other fuels such as blood glucose, plasma free fatty acids, and glycogen.\textsuperscript{1,4} The system is the means of supplying energy for exercise more than two minutes and all sub-maximal endurance exercise. The oxidative system is slower than the ATP-PCr system and anaerobic glycolysis at ATP production because it takes longer for the heart to deliver oxygen to the muscles.\textsuperscript{1}

ATP is produced through two metabolic pathways: the Krebs cycle and the electron transport chain.\textsuperscript{1,2} The Krebs cycle is responsible for NADH and FADH to enter the electron transport chain, the final result is ATP and water.\textsuperscript{2} Oxygen is required to produce ATP in the oxidative system.

Stretching Techniques

Prior to sporting activity, a warm-up routine is generally performed. A general active warm-up is believed to increase the body core temperature, heart rate, blood flow, and joint range of motion, and decrease the viscosity of connective tissue, and muscle stiffness, increasing
muscular performance and enhancing psychological performances.\textsuperscript{5,6} Though there are many variations of warm-up routines, the most common routines involve low-intensity aerobic exercise followed by static stretching. Recent research suggests that a flexibility-centered warm-up may not be the most effective way to prepare the athlete for movement or to develop long-term soft tissue adaptations.\textsuperscript{5,7-14} Therefore, a dynamic warm-up has been advocated for a pre-exercise routine. Other protocols that are used are proprioceptive neuromuscular facilitation and ballistic stretching. Though many variations exist, static and dynamic warm-ups are used most commonly.\textsuperscript{5,7-14}

Proprioceptive neuromuscular facilitation is a stretching method that combines isometric, concentric, and eccentric contractions, along with passive movement.\textsuperscript{6} Many types of PNF techniques exist, however, the hold-relax and agonist contraction techniques are the most commonly during warm-up routines. The contract relax agonist contract technique consists of applying a passive stretch to the point where the subject reports a good stretch. The subject then performs a maximum isometric contraction of the muscle following by actively moving into a more stretched position. The tester then applies more stretch for a specified amount of time.\textsuperscript{6} This type of stretch is
often performed because it is believe to increase flexibility. Wenos et al\textsuperscript{15} found that an active warm-up before the PNF-HR stretching was the most effective treatment to increase hip ROM, when compared to passive warm-ups. During the agonist contraction PNF technique, a concentric contraction of the opposing muscle is applied.\textsuperscript{16}

The effectiveness of PNF techniques involves the stretch reflex. The stretch reflex involves muscle spindles and Golgi tendon organs. There is a phasic and tonic component to the stretch reflex. A tonic response occurs in a muscle when a constant load is applied. If an unexpected increase in the load occurs the muscle would reaction to maintain the original position of the muscle. This reaction is the phasic response. Generally, over compensation occurs before the muscle returns to its original position. This is an example of how muscle spindles assist in the control of movement.

The stretch reflex plays an integral part in flexibility work. When a muscle is stretched, the muscle spindles are also stretched and impulses are then sent to the spinal cord and central nervous system. Impulses return back to the muscle causing a reflexively contraction, thus resisting the stretch. If the stretch continues over six seconds, the Golgi tendon organs respond
and send off more impulses, which then go through a similar process. However, these cause a reflex relaxation of the stretched muscle. This relaxation allows the muscle to stretch through relaxation before the extensibility limits are exceeded, causing damage to the muscle fibers, therefore providing protection from injury.\textsuperscript{17}

Ballistic stretching is associated with bobbing, bouncing, rebounding, and rhythmic motion.\textsuperscript{18} This type of stretching is not often utilized because when the muscle and its supporting connective tissues are rapidly stretched, they are not given adequate time to adapt. This increases the chance of injury. The bouncing, jerking motion of this type of stretching does not allow enough time for the stretch reflex to function properly because the Golgi tendon organs do not have enough time to have any relaxing effect.\textsuperscript{17} One variation of this technique is called plyometrics, which involves quick, powerful movements.\textsuperscript{4} This type of warm-up is commonly performed during warm-up routines. Unlike ballistic stretching, plyometrics is more closely related to a dynamic warm-up because the body is continuously moving through its full range of motion. This type of warm-up can be beneficial to performance.\textsuperscript{5,8,10,12,14}
Static stretching is commonly used for warm-up routines. It is defined as passively stretching a given antagonist muscle by placing it in maximal position of stretch and holding it there for an extended time. Many researchers have studied static stretching and well defined it. This type of stretching is well documented in increasing immediate hamstring flexibility. The rationale for a flexibility-centered warm-up is that improving flexibility is an essential element in improving athletic performance. However, recent findings suggest otherwise.

A dynamic warm-up features progressive, continuous movement. Calisthenics such as squatting and lunging movements often are paired with running drills that include forward, lateral, and change-of-directions movement. An advantage of a dynamic stretching routine is that they are more functional and sport specific. Dynamic warm-ups (DWU) have been shown to be more effective than static stretching warm-ups with enhancing muscular performance. The objectives of a DWU are to increase body temperature and heart rate, pliability of joints and muscles, and responsiveness of nerves and muscles in preparation for physical activity.
Warming-up prior to activity is important in preparing the body for activity. This is agreed upon; however the controversy lies in which warm-up protocol is best. Many types of stretching techniques exist: proprioceptive neuromuscular facilitation, ballistic, static, and dynamic. Each has its own characteristics, good and bad. The most common protocol is a static stretching warm-up, though a dynamic warm-up is quickly becoming the routine of choice.5,7-12

The Physiological Effects of Stretching

Warm-up routines play a large role in muscular performance during sports. Stretching has several physiological effects on the body. Research has shown that differences in warm-up routines affect muscle function, flexibility, and chance of injury.5,7-16,19-22

Muscle Function

Power, jumping performance, and speed are imperative in today’s competitive sports world. Recent research has suggested that utilizing a dynamic warm-up routine instead of static stretching increases power5,8, jumping performance9,10, and acceleration/speed.11 Some studies have
found a decrease in mean running speed\textsuperscript{12} or no change at all\textsuperscript{11} following a static stretching protocol.

Recent studies have suggested that following a dynamic warm-up (DWU) routine before athletic activity will enhance muscular performance more so than a static stretching warm-up (SWU).\textsuperscript{6,8,11,12,14} This has been greatly debated in recent years. It is important for the athlete, coach, and others with athletic related careers to know the best warm-up procedure to produce the best results for muscular performance.

In a review of the literature of muscle function related to power and agility, a DWU was more beneficial than a SWU or no warm-up (NWU), according to McMillian et al\textsuperscript{5} and Yamaguchi et al.\textsuperscript{8} For the most part, SWU and NWU revealed no differences for the medicine ball throw and T-shuttle run, but the SWU was associated with better scores on the 5-step jump.\textsuperscript{5} Yamaguchi et al\textsuperscript{8} found that leg extension power after 30 seconds of static stretching of the plantar flexors, hip extensors, hip flexors, and quadratus femoris was not different from that after no stretching. However, a DWU enhanced leg extension power. If leg extension power is not affected by a SWU or NWU, a static stretching routine would lack importance.
In studies conducted by Thompsen et al\textsuperscript{9} and Faigenbaum et al\textsuperscript{10} it was found that a DWU significantly enhanced jumping performance in athletic women. Furthermore, wearing a vest weighted with 2\% body mass was more effective than a DWU alone. However, a vest weighted with 6\% body mass had detrimental effects on jumping performance.\textsuperscript{10} Another study showed no significant differences between different warm-up protocols.\textsuperscript{11}

Speed is imperative in several sports, such as soccer, gymnastics, and running, just to name a few. Little et al\textsuperscript{11} recommends that a DWU is optimal for high speed performance sports. Though 20 meter maximum speed times were significantly faster for a SWU and DWU than NWU, a DWU is more functional. Another study found different results. There was a decrease in mean running speed following an acute SWU protocol, while no modifications were observed after a DWU.\textsuperscript{12} After reviewing the literature on muscle function it appears that a DWU is more beneficial than a SWU preceding athletic activity, especially ones that require speed and power.

**Flexibility**

Flexibility is an important component for activities of daily living and sports, particularly ones that call for
increased mobility. A lack of flexibility may increase the chance of injury. \(^4\) Nelson et al\(^{18}\) compared eccentric training and a static stretching routine to determine which protocol improved hamstring flexibility the most. Eccentric training was performed actively with a black Theraband while the athlete was simultaneously pulling the hip into full flexion with the arms and resisting hip flexion during the entire range of motion. With eccentric actions, the muscle’s ability to resist force is approximately 30% greater than with concentric actions, which theoretically produces greater strength gains.\(^1\) It was found in the study that both approaches appeared to be equally effective after six weeks.\(^{18}\) Bandy et al\(^{23}\) conducted a study to examine the length of time (0, 15, 30, or 60 seconds) a muscle should be sustained in a stretch position to maximally increase flexibility. After subjects were put through a 6 week static stretching program they found that the most effective duration of stretching is 30 seconds for the hamstring muscles. With a hold time of 30 seconds, the duration of hamstring flexibility is inconclusive. DePino et al\(^{20}\) found that knee extension range of motion lasted 3 minutes after the cessation of the static stretching protocol. Contrary to these results, Ford et al\(^{21}\) found
that gains in hamstring range of motion lasted for the entire testing duration of 25 minutes.

It has also been theorized that certain warm-up routines play a part in increasing or decreasing injury rates.\textsuperscript{7,13} Muscle strains are common during sport participation and represent 41\% of all injuries reported in the English professional football clubs.\textsuperscript{24} With this being known, much curiosity is brought about to answer the question why. Dadebo et al\textsuperscript{13} carried out a study to investigate the relationship between current flexibility training protocols, including hamstring strain rates in English professional football clubs. 30 of the 46 teams during the 1998/99 season, all from different athletic levels and divisions, completed questionnaires. Static stretching was the most popular stretching technique used among the clubs in this study. There was no significant difference found among divisions for injury rates, though it is suggested that there is a relationship between type of stretching employed and hamstring injury rates.\textsuperscript{13}

Measurements

Tests that tax the anaerobic glycolytic system usually last from 20-50 seconds. The formation of ATP, mainly from
glycolysis takes place between 20 and 35 seconds of maximum exercise. Different tests have been established to anaerobically test the system: 30-second Wingate test, DeBruyn-Prevost constant-load test, and sport specific tests.

The 30-second Wingate test was first described in 1974 and has been used since then to assess the characteristics of anaerobic performance. The test can be performed on any stationary bicycle or a Lode cycle ergometer. During this test, the subject is to pedal as fast as possible for duration of the test. The resistance load in the leg test is 0.075 kilograms per kilograms of body weight (75g/kg of body weight) for the Lode ergometer.

Mean power, peak power and end power can be measured during a Wingate test. Muscular performance in both the upper and lower extremities can be measured using the Wingate 30 second anaerobic test. Gullstrand et al used the Wingate test to test ice hockey and soccer players. The results were similar for both groups. Skating and running times were faster when the subjects produced more mean power during the test. The 30-second Wingate test-retest reliability ranges from 0.90 to 0.98 for mean power and peak power.
The DeBruyn-Prevost constant-load test requires working to exhaustion at a constant power output. The workload and pedal rate varies between men and women. When the subject is unable to maintain the required pedal rate, the test is completed. The reliability for this test is significantly less than the Wingate test, at \( r = 0.77 \).

Sport-specific tests are made depending on the sport. These can be compared to the 30-second Wingate test; however the tests are developed toward the specific sport (i.e. running, ice-skating, soccer and basketball dribbling). For sport-specific tests, time and/or distance are usually measured, and power is then calculated.\(^{25}\)

Different tests can be used to measure power when the anaerobic glycolytic system is at the peak of its contribution. The Wingate test is the most reliable, reproducible, and widely accepted test to measure power.

Summary

Many varieties of warm-up and stretching routines exist. Though some coaches favor some over others, the chosen routine is not always the most beneficial for athletic performance. Certified Athletic Trainers should be aware of different warm-up routines and what is in the
best interest of the athlete. What is the optimal choice for athletic performance? This has been debated by multiple researchers and it has been shown that athletic performance is enhanced after a dynamic warm-up.\textsuperscript{6,8,11,12,14} However, some studies have shown insignificant or no difference following a static stretching of dynamic protocol.\textsuperscript{11,12} This is a concern since warm-up and stretching routines are used in the athletic world everyday.
APPENDIX B

The Problem
The Problem

Statement of the Problem

The purpose of the study is to examine the differences between a static stretching protocol, a dynamic stretching protocol, and no stretching and their effects on mean power output during a 30-second anaerobic bicycle test. It is important to have knowledge about which stretching protocol will improve muscular performance the greatest because it may decrease the chance of an injury occurring to that body part. A dynamic warm-up allows the athlete to move in a more functional pattern than static stretching. Static stretching elongates muscles in a way that a stretch is obtained, however the body may respond differently to a stretch that is more related to the demands of their sport. The more the body is moved, the heart rate will increase more, thus increasing body temperature and muscle elasticity. Therefore, it is important to study the effects of certain warm-up protocols on anaerobic performance.
**Definition of Terms**

The following terms are used throughout the study and will be define pertaining to this specific study:

1) **Static Stretching Warm-up (SWU)** – Stretching routine that includes stretching the quadriceps, abductors, hip flexors, adductors, hamstrings, glutes, and gastrocnemious/soleus. Each stretch is performed bilaterally and held for 20 seconds.

2) **Dynamic Stretching Warm-up (DWU)** – Stretching routine that includes high knees, drop lunges, flick backs, lateral shuffles, and heel-toe walks. The subject will perform 20 repetitions bilaterally.

3) **30-second Anaerobic Bicycle Test** – 30 second maximal cycling test performed on a Lode cycle ergometer which measures mean power output, peak power, rate to fatigue, total work, and minimum power. These values are collected over 30 seconds and extrapolated to one minute values.

**Basic Assumptions**

The following are basic assumptions for this study:

1) The subjects performed the warm-up routines and tests to the best of their ability.
2) The 30-second Wingate test is a reliable and valid test.

**Limitations of the Study**

The following are limitations for this study:

1) The subjects were limited to Division II athletes from California University of Pennsylvania.

2) The subjects were volunteers.

3) The subjects were all performing warm-up routines which may be new to them so learning issues may affect the consistency of the procedures.

**Significance of the Study**

Athletic performance plays an essential role in athletics today. Typically a warm-up is performed before activity consisting of some sort of low intensity aerobic exercises followed by a stretching protocol. Many different protocols exist, however much controversy remains between static stretching and a dynamic warm-up. Static stretching is the type of stretching takes the muscle to its end range and maintains the position for a specified duration\(^\text{16}\) and is commonly used as a warm-up. Another commonly used form of stretching is known as a dynamic warm-up (or dynamic flexibility). There are many
variations of a dynamic warm-up, but most consist of progressive continuous movement. It has been argued that a static stretching protocol before activity decreases performance and a dynamic warm-up enhances it.\textsuperscript{6,8,11,12,14}

A dynamic warm-up is beginning to be the warm-up stretching protocol of choice by many coaches and athletic trainers. In dynamic stretching the muscles are contracted actively and rhythmically to stretch the target muscle. The dynamic warm-up has been shown to increase hamstring range of motion after a minimum of four weeks, however, not much research has been conducted concerning the acute effects.

There have been several studies that examine the acute effects of different types of stretching on power, jumping, and speed but not on anaerobic performance.\textsuperscript{5,8-11} Recent research indicated that the static stretching approach to movement preparation may not be the most effective way to warm-up, because it may not prevent injury or improve performance.\textsuperscript{7} This study also concluded that a more functional approach to movement preparation is more effective because it raises the body temperature and increases range of motion.

Since there is a lack of evidence on acute effects of static stretching and dynamic stretching, this study will
examine if one protocol supersedes the other. The findings will possibly cause reason for coaches and athletic trainers to implement the more effective pre-activity protocol for anaerobic performance.
APPENDIX C

Additional Methods
Appendix C1

Informed Consent Form
Informed Consent Form

1. "Tiffany M. Estes, who is the researcher, has invited me to participate in a research study at this institution. The title of the research is "The Effects of Static and Dynamic Stretching Protocols on the 30-second Wingate Test." This study has been approved by the California University of Pennsylvania Institutional Review Board, and approval is effective from 02/25/08 to 02/25/09.

2. "I have been informed that the purpose of this research study is to compare the effects of dynamic stretching, static stretching, and no stretching on Wingate Test performance in Division II male athletes. I understand that 20 male athletes from California University of Pennsylvania will be tested for research purposes, and I have been invited to participate since I am a current student athlete."

3. "My participation is voluntary and will involve signing this form and completing a demographic form before beginning the study. For the experimental portion of the study, I will be asked to do a five minute warm-up on a stationary bicycle. I will then be asked to do a static stretching protocol, a dynamic stretching protocol, or no stretching, followed by the Wingate Test. The Wingate Test is a 30-second anaerobic performance test. It is used to measure power output of the lower body. The test consists of pedaling as fast as possible for the entire 30 seconds against a resistance, which is determined by my body weight. I will participate in this study on six separate days, so that I complete each stretching protocol twice. There will be at least one day in between each testing session, but no more than 4."  

4. "I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. The possible risks and/or discomforts include possible nausea, soreness, and fatigue due to activity. To minimize these risks and discomforts, the researcher has included a proper five minute warm-up routine and a two minute cool-down."

250 University Avenue
California, PA 15418-1394
724-938-4562/2350
724-938-4342 FAX
www.cup.edu
5. "I understand that in case of injury, I can expect to receive treatment or care in the Hamer Hall Athletic Training Facility at California University of Pennsylvania, which will be provided by the student researcher, Tiffany M. Estes, or another Certified Athletic Trainer, either of whom can administer emergency or rehabilitative care. Additional services needed for prolonged care past three days will be referred to the team physician. I understand that I will be responsible for payment of any services provided by the team physician, or other medical professional, above or beyond those provided by the student researcher or other Athletic Trainer."

6. "There are no feasible alternate procedures available for this study."

7. "There are no direct benefits to me as a participant in this research study."

8. "I understand that the results of this research study may be published but my identity will not be revealed. In order to maintain confidentiality of my records, Tiffany M. Estes will maintain all documents in a secure location, which can only be accessed by the student researcher and the researcher's advisor. Confidentiality will be maintained by my being assigned a number and I will be referred to only by that number during testing. After completing all data analysis, the records will be destroyed."

9. "I have been informed that I will not be compensated for my participation and there will be no cost to me."

10. "I have been informed that any questions I have concerning the study or my participation in it, before or after my consent, will be answered by Tiffany M. Estes, est9759@cup.edu, 947 Cross St. Apt #3, California, PA 15419, (614) 582-5859, and Dr. Bruce Barnhart, barnhart@cup.edu, 250 University Avenue, Box #14, California, PA 15419, (724) 938-4356."

11. "I have read the above information. The nature, demands, risks, and benefits of the study have been explained to me. I knowingly assume the risks involved and understand that I may withdraw my consent and end my participation at any time without penalty.
by contacting the researcher. I understand that the investigator may terminate my participation in the study without my consent if it is found that I falsified any information prior to participation in the study. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this form will be given to me upon request.”

Subject’s Name (print) ...........................................

Subject’s Signature ___________________ Date _______

12. “I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this study, have answered any questions that were raised, and have witnessed the above signature.”

13. “I have provided the subject/participant a copy of this signed consent form if requested.”

Investigator’s
Signature ___________________ Date _______
Appendix C2

Institutional Review Board (IRB)
PROTOCOL for Research Involving Human Subjects

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

Project Title: The Effects of Static and Dynamic Stretching Protocols on the 30-second Wingate Test

Researcher/Project Director: Tiffany M. Estes

Phone #: 614-382-5859 E-mail Address: est0759@cup.edu

Faculty Sponsor (if required): Dr. Bruce Barnhart

Department: Health Science and Sport Studies

Project Dates: January 2008 to May 2008

Sponsoring Agent (if applicable):

Project to be Conducted at: California University of Pennsylvania

Project Purpose: ☑ Thesis ☐ Research ☐ Class Project ☐ Other

Keep a copy of this form for your records.

Required IRB Training

The training requirement can be satisfied by completing the online training session at http://srate.cdeh.nih.gov/. A copy of your certification of training must be attached to this IRB Protocol. If you have completed the training at an earlier date and have already provided documentation to the California University of Pennsylvania Grants Office, please provide the following:

Previous Project Title

Date of Previous IRB Protocol
Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(es) or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual.

*The purpose of this study is to compare the effects of dynamic stretching, static stretching, and no stretching on Wingate Test performance. The main hypothesis of this study is that mean power output will be greater following dynamic stretching than static stretching and no stretching. Power output will be measured using the Wingate Test. All data will be analyzed using SPSS version 14.0 for Windows with a 0.05 alpha level. Scores for each subject on the dependent variable, the power output during the Wingate test, will be used. Hypothesis one will be analyzed using an analysis of variance.

2. Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.

   a. How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.

   *The possible risks and/or discomforts include possible nausea, soreness, and fatigue due to activity. All subjects will be fit individuals that participate in collegiate athletics at California University of Pennsylvania. To minimize these risks and discomforts, the researcher has included a proper warm-up consisting of a five minute intermittent warm-up (alternating 30 seconds of exercise and 30 seconds of rest) before any stretching or testing, and a two minute cool down immediately following the test. There is a possibly of increased risks and/or discomforts since a prize will be given to the subject with the highest power output. In case of injury, the subject can expect to receive treatment or care in the Hamer Hall Athletic Training Facility at California University of Pennsylvania, which will be provided by the student researcher, Tiffany M. Estes, or another Certified Athletic Trainer, either of whom can administer emergency or rehabilitative care. Additional services needed for prolonged care past three days will be referred to the team physician. The subjects understand that they will be responsible for payment of any services provided by the team physician or other medical professional above or beyond those provided by the student researcher or other Athletic Trainer.

   b. How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled
persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.

*The purpose of this research study is to compare the effect of dynamic stretching, static stretching, and no stretching on power output during the 30-second Wingate test in Division II collegiate athletes. In this study it is important to have 20 male athletes to determine which stretching technique will be most beneficial to athletes. Participation will be voluntary. The subjects will not be required or have any influence from someone in authority, for example a coach. The researcher will contact possible participants by e-mail asking if they would be interested in participating. Anyone interested will be asked to attend a meeting about the study and sign up for days to be tested.

c. How will you obtain informed consent from each participant or the subject’s legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.

*The subject’s participation will involve completing an informed consent form before beginning the study.

d. Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects’ responses and provisions for maintaining the security and confidentiality of the data.

*The results of this research study may be published, but the names and identity of the subjects will not be revealed. In order to maintain confidentiality of the subjects’ records, Tiffany M. Estes will maintain all documents in a secure location, which can only be accessed by the student researcher and the researcher’s advisor. Confidentiality will be maintained by the subjects being assigned a number and the subjects will be referred to only by those numbers during testing. After completing all data analysis, the records will be destroyed.

3. Check the appropriate box(es) that describe the subjects you plan to use.

- [ ] Adult volunteers
- [X] CAL University Students
- [ ] Other Students
- [ ] Prisoners
- [ ] Pregnant Women
- [ ] Physically Handicapped People
- [ ] Mentally Disabled People
- [ ] Economically Disadvantaged People
- [ ] Educationally Disadvantaged People
- [ ] Fetuses or fetal material
- [ ] Children Under 18
- [ ] Neonates

4. Is remuneration involved in your project? [ ] Yes or [X] No. If yes, Explain here.
5. Is this project part of a grant? ☐ Yes or ☒ No  
If yes, provide the following information:

Title of the Grant Proposal ______________________________________
Name of the Funding Agency ______________________________________
Dates of the Project Period ______________________________________

6. Does your project involve the debriefing of those who participated? ☐ Yes or ☒ No  
   If Yes, explain the debriefing process here.

7. If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix __ in the Policies and Procedures Manual.
Project Director’s Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes in the research must be approved by the IRB before they are implemented.

Professional Research

Project Director’s Signature

Department Chairperson’s Signature

Student or Class Research

Student Researcher’s Signature

Supervising Faculty Member’s Signature if required

Department Chairperson’s Signature

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved;
4. provides adequate debriefing of human participants;
5. provides adequate follow-up services to participants who may have incurred physical, mental or emotional harm.

Approved ☐ Disapproved ☐

Chairperson, Institutional Review Board

Date

Draft, April 7, 2005
Appendix C3

Letter to Team Coach
I, Dennis Laskey, give Tiffany M. Estes permission to conduct a research study with California University of Pennsylvania athletes with IRB approval from the institution.

Dennis Laskey
Team Coach of
California University of Pennsylvania

Date
3/5/08
Appendix C4

Demographic Sheet
Demographic Questionnaire

Subject Number: _____

Age: _____

Height: _____  Weight: _____

Sport: _________________

Have you ever had any injuries to the lower extremity in the last six months?  Injury is defined as having missed three or more days from sport participation.
   Yes _____  No _____

Are you involved in any extracurricular training program?
   Yes _____  No _____
   If yes, please explain _______________________________
   _______________________________________________
   _______________________________________________
Appendix C5

Static Stretching Protocol
Appendix C6

Dynamic Stretching Protocol
A) High Knees (gluteals and hamstrings) B) Drop Lunges (gluteals and hip flexors) C) Flick Backs (quadriceps and hip flexors) D) Lateral Shuffles (adductors and abductors) E) Heel to Toe Walks (gastrocnemius/soleus)
REFERENCES


19. Marek, SM; Cramer, JT; Fincher, AL; Massey, LL; Dangelmaier, SM; Purkayastha, S; Fitz, KA; Culberston, JY. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *Journal of Athletic Training*, 2005;40(2):94-103.


ABSTRACT

Title: THE EFFECTS OF STATIC AND DYNAMIC STRETCHING PROTOCOLS ON A 30-SECOND ANAEROBIC BICYCLE TEST.

Researcher: Tiffany M. Estes

Advisor: Dr. Bruce Barnhart

Date: April 30, 2008

Research Type: Master’s Thesis

Purpose: The purpose of the study was to examine the differences between a static stretching protocol, a dynamic stretching protocol, and no stretching and their effects on mean power output during a 30-second anaerobic bicycle test.

Problem: Recent research has found that different stretching protocols have different effects on anaerobic performance.

Method: Fifteen male Division II athletes volunteered for this study. Each subject was tested on three different days. All subjects performed the randomly selected stretching protocol, followed by a 30-second anaerobic bicycle test. Immediately following the test a two minute cool-down was completed on the ergometer.

Findings: A significant effect was found for mean power output (F(1,14) = 6.352, P = 0.005). Mean power was higher under a dynamic stretching protocol than a static stretching protocol and control.

Conclusion: The study revealed that stretching protocol has a significant effect on mean power output during anaerobic performance in Division II collegiate athletes.