THE EFFECT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION VS STATIC STRETCHING VS CONTROL ON THE HAMSTRING MUSCLE GROUP FOR FLEXIBILITY, PEAK TORQUE, AND POWER

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
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THESIS APPROVAL

Athletic Training

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ACKNOWLEDGEMENTS

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INTRODUCTION

Athletes have been competing in physical activity since people can remember. For those who watch competitions on television, especially the Olympics, we witness athletes preparing for their events in almost ritualistic ways. The most common sight is an athlete stretching before their event, loosening up their muscles before competition.

Whether in competition or practice, from “weekend warrior” to elite athlete, stretching has always been a mainstay in the warm-up and exercise routines of the physically active. Since the first day of gym class, stretching has been embedded into our minds as something that must be done to prepare for physical activity. It is the public perception that stretching improves flexibility of the muscles and tendons, as well as improving range of motion (ROM).\(^1\)\(^2\) However, a meta-analysis was done suggesting that although stretching helps it does not significantly reduce the incidence of injury.\(^3\) Despite not finding a significant link between increases in flexibility and ROM. Research has shown that stretching does increase flexibility and ROM.\(^4\)\(^\text{10}\)
There are multiple ways to stretch. The most well known and frequently used is the traditional static stretch. This is performed by simply relaxing the muscle and lengthening it.\textsuperscript{1,2} This stretch can also be augmented by contracting the muscle group that opposes the group being stretched. To understand the reasoning behind how static stretching works the physiology of how the body reacts to stretching needs to be understood. The stretching of a muscle starts with a basic component, a sarcomere. This is not the most basic component of a muscle, but rather a basic unit of contraction in a muscle. When a sarcomere contracts the thick and thin myofilaments overlap, while when stretched these two filaments do not overlap as much. Once all the sarcomeres in the stretched muscle have reached their full length and cannot stretch any further the connective tissue takes over in handling the stretch-tension. This tension-contraction aligns the collagen fibers in the connective tissue in the same direction as the tension on the tissue. As more fibers are stretched the longer the muscle will become. When the muscle is stretched so are the muscle spindles in the muscle. The muscle spindles sense how quickly the muscle is lengthening. As this occurs the muscle spindles send signals to the central nervous system which in turn
responds by contracting the lengthening muscle. The strength in the contraction is proportional to how quickly the muscle is lengthening. By holding a muscle in a lengthened state over time allows the muscle spindles to become accustomed to the new length that the muscle spindle is at and therefore it reduces the signals to the central nervous system resulting in less of a contracting response. However, the muscle is still contracting and to help counter act this, the muscle has golgi tendon organs (GTOs). The GTOs, sense the tension in the muscle from the contraction. The GTOs respond to this contraction by releasing a muscular contraction inhibitor. This inhibitor is sent to the muscle of the side being stretched which reduces the contractions of the spindle fibers.\textsuperscript{2,4-8} This is possible to overcome the contractions as the signals sent by the GTOs to the central nervous system are stronger then the signals sent by the muscle spindles.

Although gains in flexibility and ROM can be attained using traditional static stretching, research has shown a drawback that is not commonly known. The drawback is that strength and power show signs of regression after stretching. For example, a study done by Cramer et al\textsuperscript{5} showed decreases in peak torque production in both dominant and non-dominant lower extremity muscle groups. Another
drawback to static stretching was reported by Power et al.\textsuperscript{6} They noted decreases in force production in the quadriceps, hamstring, and plantar flexor muscle groups studied. McNeal and Sands\textsuperscript{7} looked at the effects of static stretching on lower extremity power through jump performance. This study noted a decrease in jump performance, strength, and power. In the research, an explanation as to why this decrease occurs is that stretching inhibits the maximal voluntary contraction forces.

As mentioned earlier, one alternative to traditional static stretching is proprioceptive neuromuscular facilitation (PNF). Other techniques exist, but this research will focus on PNF stretching. When these stretches were being developed, the focus was to improve proprioception, range of motion, and motor control.\textsuperscript{9} Past research suggests that PNF shows slightly better, but not significant, gains in flexibility and ROM.\textsuperscript{10} Previous research presents conflicting information on improvements in strength, but many of the studies favor gains in strength.\textsuperscript{10-12}

Looking at the history of research for both stretching techniques, many studies have been done on flexibility, ROM, peak torque, power, strength, etc. However there are few studies that compare static stretching to PNF. It is
the purpose of this research to look for any differences between PNF and static stretching in flexibility, peak torque, and power.

Besides having limited research comparing PNF and static stretching previous literature shows small sample sizes used in those researches.\(^5\)\(^-\)\(^7\),\(^10\) Past research also shows that in testing the lower extremity, the limb was tested in an open kinetic chain environment. This is problematic as the lower extremity functions mainly in a closed kinetic chain environment being in contact with the ground forces.\(^5\) A goal of this study is to add to the pool of information attempting to further the knowledge and understanding of PNF stretching and how it compares to traditional static stretching.

There are several questions regarding PNF stretching and how they compare to static stretching of the lower extremity. The following questions will be addressed by the research: 1) What is the difference between PNF stretches versus static stretches for flexibility? 2) What is the difference between PNF stretches versus static stretches for peak torque? 3) What is the difference between PNF stretches versus static stretches for power?
METHODS

The methods section will serve to give an overview as to how the experiment will be conducted. It will include Research Design, Subjects, Pilot Research, Instrumentation, Procedures, Hypotheses, and Data Analysis.

Research Design

This study was a quasi-experimental design, as the subjects were a sampled convenience. The experiment was designed to control as many variables as possible, to improve internal validity of this study.

The dependent variables were flexibility, concentric peak torque of the hamstrings, and single leg standing broad jump measurements. The independent variable was the type of stretching protocol performed (static stretching, PNF hold-contract, and control). Each participant completed each of the protocols. Data was collected on the participants for flexibility measured in centimeters, concentric peak torque production in Newton-meters of the hamstrings at velocities of 60°/sec, 180°/sec, and 300°/sec, and the single leg standing broad jump test measured in centimeters. In order to complete all of the
three areas, a protocol was established for completion of each variable. The order of the protocols for the subjects was determined on the first day of the research, which was also used as a familiarization period. The following days included a five-minute bike warm-up first, then the subject performed the stretching protocol that was determined on the first day. Once the protocol was completed the subject had flexibility measured by the modified sit and reach, followed by the peak torque production, and single leg standing broad jump tests.

Some consistency was maintained by having only one examiner complete all of the necessary measurements and recording of data. Also, the equipment and environment remained the same for each of the participants.

Subjects

There were 23 participants comprised of students from California University of Pennsylvania. The subjects consisted of both undergraduate and graduate students in the athletic training program as well as physically active college students around campus. Each participant completed an activity index test (Appendix C2)\textsuperscript{13} to see if they were considered physically fit, but not necessarily the caliber
of an elite athlete. Every participant was required to partake in all elements of the experiment with no exceptions. If this could not be done, due to a recent lower leg injury or surgery to the lower extremity for example, then the participant was exempt from the study. Confidentiality of each participant was maintained.

This sample due to the age of the participants is limited in its application as it only examines a collegiate or physically active population. Due to the inability to apply the results to every age group, as each age group has its own needs and differences, it should be noted that applications to various populations not used in this study should be made with caution.

Each participant read and signed an Informed Consent Form (Appendix C1) which included the purpose of the study, research involved, researcher’s contact information, and the right to remove him or herself from the study at any time without penalty. Subjects also had their own Data Collection Form (Appendix C3). This form had exclusion criteria questions to see if volunteers were able to participate in the study. As the study was targeting healthy individuals, these questions asked if the volunteer had a recent injury or surgery to the lower extremity. If so then the volunteer was excluded from the study without
penalty. This was done so that lower extremities that had surgery or recent injuries did not skew the data. The form also had a table to place data recorded from testing done in the study. Additional information such as age, gender, height, and weight was recorded for further statistical analysis (Appendix C3). For confidentiality purposes a number code was used for identification between data collection forms.

Pilot Study

A pilot study was conducted using two subjects that met the requirements of the study. By performing the pilot study, the researcher became familiar with all the procedures. Also, by becoming familiar with the experiment, the researcher was able to note any problems that could arise, which resulted in changes to the protocol to improve the experiment. Overall the pilot study was conducted in the same manner as the procedures. The subjects used in the pilot research were given the Informed Consent Forms (Appendix C1). After the pilot study was performed the researcher found no need for any corrections to the methods of the research.
Instrumentation

This section discussed what instruments were used, the method in which they were used, and reliability and validity of these instruments. Instruments used in this research were the modified sit and reach block, Biodex™ System 3 Multi-Joint Dynamometer, and a measuring tape. The instruments were used to measure flexibility, peak torque, and power respectively.

The modified sit and reach test was used to measure flexibility. A sit-and-reach box was used to record the flexibility of the subject. The box was self-made by the researcher. The height of the box was 12 inches high and a stick centered on the box with 15 inches of the stick protruding towards where the subject would sit. This is so that the start and end points of the test could be marked and recorded. Three trials were made and measurements were taken in centimeters for each participant and the best score was used for analysis. Modified sit and reach has been used before and its validity and reliability are proven for testing flexibility.\textsuperscript{14-15}

The Biodex™ System 3 Multi-Joint Isokinetic Dynamometer was used to measure concentric peak torque values of the left and right hamstrings in the subject. It
is a piece of equipment that is considered to be reliable and valid when relating to isokinetic strength testing.\textsuperscript{16,17} The Biodex\textsuperscript{\textregistered} is applicable to a diverse array of experimental situations; with the end result always being the same, reliable and valid. The protocol that was used for measuring peak torque was a three-speed 60°/sec, 180°/sec, and 300°/sec concentric knee flexion protocol.

The single leg standing broad jump test was used to measure power in the study. The single leg standing broad jump for distance has proven to be a method of testing that is reliable by the research it was used in.\textsuperscript{19-23}

The Data Collection Form (Appendix C3) provided necessary space for the three measurements taken from the sit and reach, three trials of each leg for single leg broad jump, and a space for information from the Biodex\textsuperscript{\textregistered} System 3 for the peak torque reading of each leg at the three speeds of 60°/sec, 180°/sec, and 300°/sec. Spaces for demographical information were also place on the collection form. This form allowed for the collection process to remain consistent and increase the internal validity of the experiment.
Procedures

The California University of Pennsylvania Institutional Review Board for the Protection of Human Subjects Form (Appendix C4) was completed and submitted for approval to conduct the study. Also, all data and information that was documented and recorded in the experiment was kept in a secure location with access granted only to the researcher and his advisor.

On the first day of research, the subject read and signed the Informed Consent Form (Appendix C1). They answered demographic questions and went through a familiarization phase of the equipment that was used, as well as stretching techniques. Also the order in which they went through the protocols was determined on this day. The order was determined at random from the six possible arrangements of the protocols. This was accomplished by having the subject pick from a hat that had six strips of paper. Each strip had one of the six possible arrangements of the protocols. Starting with the first day and each day following when the research was done a minimum of 24 hours passed to allow for rest and recovery of the subject. On the day after the familiarization day and following rest
period, protocols were done in the order that was determined on the first day and data collection started.

Following past research designs the warm-up protocol for this experiment consisted of a five minute bike workout on a Life Fitness 9500HR Life Cycle exercise bike. The subject would sit on the bike and the researcher would adjust the seat height so that the knee would be at approximately 30° of knee flexion. The subject pedaled the bike at 70 RPMs and then maintained this speed for five minutes. The warm-up protocol was used because of reliability and validity from this protocol being used in past research.

Once warm-up was completed, one of the three protocols was implemented upon the subject: proprioceptive neuromuscular facilitation (PNF) hold-relax stretching, passive static stretching, or control. PNF protocol started with the subject in a supine position with arms to their side and legs straight. The researcher would then grasp the ankle and straight raise the leg mentioning to the subject to notify the researcher when the subject felt a stretch. Once a stretch was felt the researcher would start the timer to perform 10 seconds of passively stretching the hamstring. At five seconds left the researcher would count a loud to notify the subject that
they will be contracting, at the end of the five second count the researcher will call out contract which the subject would then for six seconds create an isometric contraction the hamstrings. As the subject is contraction the researcher out loud counts down the six seconds at the end of the countdown the researcher will call out relax. The subject should relax and the researcher would then apply more stretching tension mentioning to the subject when they fell a stretch and stop adding tension when the subjects notes the added tension. The portion of the stretch will last 30 seconds of passively stretching the hamstrings. This was done three times for each leg with 15 seconds of rest in between each stretching. The static stretching protocol consisted of three bouts of 46 seconds for each leg with 15 seconds rest in between each stretching in performed in the same position as the PNF protocol and performed in the same manner. It should be noted that 46 seconds are used for static stretching as the PNF stretch takes 46 seconds to perform. The control protocol required the subject to do no stretching and lie in a supine position for six minutes which was the average amount of time it took to perform the other two protocols.

For the modified sit and reach test, subjects removed their shoes and sat on the floor with head, back, and hips
against the wall, knees fully extended, feet shoulder-width apart and soles of the feet held flat against the end of the sit-and-reach-box. With hands on top of each other, palms down, and legs flat against the floor, the subjects reached along the measuring line as far as possible keeping the head, back, and hips against the wall, but were allowed to have the shoulders leave the wall. This was marked as the start or zero point. After this was established the subject then was allowed to reach forward allowing the head and back to leave the wall and held their position until the measurement was recorded. Legs must remain straight, soles of feet against box, and fingertips of both hands should reach evenly along measuring line. Scores were recorded to the nearest centimeter. After each attempt the distance was recorded with the best score of three being used for data analysis.14-15

Setup of the Biodex™ System 3 followed the guidelines provided by Biodex™ Medical System Incorporated Applications and Operations Manual.18 The subject was seated in the chair with the chair position set at 90° chair rotation, dynamometer rotated at 90° facing toward the lateral side of the leg. With knee attachment attached and aligned with properly with the dynamometer. The subject was moved forward to be lined up with axis of
rotation of the subject’s knee and axis of rotation of
dynamometer, adjusting the seat height and distance of
dynamometer from patient for fine adjustment. Finally the
knee attachment was adjusted so that the pad was proximal
to medial malleoli. The software test protocols were a
three velocity 60°/sec, 180°/sec, and 300°/sec concentric
knee flexion test to gather information on peak torque of
the hamstrings.

The single leg standing broad jump was recorded in
centimeter increments and utilized for data analysis. The
test was performed with the following guidelines. A
line was drawn on the floor to designate the starting
point. Subjects chose which leg to start testing first.
The subject would stand behind the line with toes just
touching the line, and then they would stand on one foot.
The leg not being test was to be maintained in 90° of knee
flexion during the trial. For a period of five seconds,
the participant balanced and that foot. Once the five
seconds elapsed they would then jumped forward for as much
distance as possible. The landing was required to be made
with the take-off leg, and stick the landing which would be
maintained for three seconds after landing without moving
their landing foot and without touching the ground with
their other leg, arms, hands, or any other part of their
body. If the landing position was not maintained for the full five seconds then the subject went back to the starting position and repeated the trial over. The measurement was taken in centimeters from the starting line where the front of the foot was to the front of the participant’s foot where they landed. The participant was to complete three attempts with the best distance being utilized for analysis. All of the data was recorded within the Data Collection Table (Appendix C3) for each participant.
Hypothesis

The following hypothesis is based on the literature reviewed when developing this research study and the insight of the researcher.

1. PNF hold-relax stretching will show greater improvements in flexibility and will show less of a decrease in power and peak torque compared to passive static stretching.

Data Analysis

The level of significance for this study will be set at $\alpha = .05$ for all statistical tests in order to test the hypotheses.

Hypothesis 1: An independent MANOVA was used to determine differences in flexibility, peak torque and power between PNF hold-relax and passive static stretching, and control.
RESULTS

The purpose of this study was to examine the differences between three stretching protocols. This research was designed to see how the muscle would perform after an acute bout of stretching. The two stretching protocols used were proprioceptive neuromuscular facilitation (PNF) hold-relax stretching, passive static stretching, and control.

Data collected from the subjects included demographical information, activity level, flexibility, power in each leg, and peak torque at three different isokinetic speeds for each leg.

Demographic Data

The sample of this study was comprised of 23 college level students (12 male, 11 female) from California University of Pennsylvania. The subjects’ age in years (22.39 ±2.84), height in centimeters (172.62 ±9.6), and weight in kilograms (79.5 ±18.66) were obtained. Using the height and weight BMI was calculated (26.5 ±4.8). Before testing began, activity level was recorded using an activity index (57 ±26.24) to determine if subjects participating met the
requirement of being physically active for the research, which the researcher set the minimum score of 25 which would indicate at least a moderately active individual\textsuperscript{13}. 

Hypothesis Testing

The following hypotheses were tested for the study. All of the hypotheses were tested at the .05 alpha level.

Hypothesis: PNF hold-relax stretching will show greater improvements in flexibility and less decrease in power and peak torque compared to passive static stretching.

A Multivariate Analysis of Variance (MANOVA) was done for the relationship in stretching protocol (PNF hold-relax, passive static, and none) on flexibility, power, and peak torque (Table 1 and 2). No significant effect was found ($\text{Lambda}_{18,116} = .762, p > .05$). Flexibility, power, and peak torque was not significantly influenced by the stretching protocols.

Conclusion: There was no difference in gains of flexibility or loss in power and peak torque between PNF hold-relax and passive static stretching.
Table 1. MANOVA of Stretching Protocols on Flexibility, Power, and Peak Torque

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Additional Findings

A one-way between-subjects MANCOVA was calculated to examine the effect of stretching protocol on the peak torque values (60°/sec, 180°/sec, and 300°/sec) for the left and right legs, covarying out the effect of body mass index (BMI). BMI was significantly related to peak torque ($\Lambda_{6,60} = .674, p < .001$). Follow-up univariate ANCOVAs indicated significant influence by BMI in the left leg at 60°/sec ($F_{1,65} = 16.737, p < .001$), right leg at 60°/sec ($F_{1,65} = 10.403, p < .01$), left leg at 180°/sec ($F_{1,65} = 15.527, p < .001$), right leg at 180°/sec ($F_{1,65} = 8.875, p < .01$), left leg at 300°/sec were ($F_{1,65} = 11.744, p < .001$), right leg at 300°/sec ($F_{1,65} = 5.918, p < .05$) (Table 3).

Conclusion: Evidence in this study suggests a positive relationship occurs between an individual’s BMI score and peak torque values. As BMI increases so do peak torque values.
Table 3. MANCOVA for Body Mass Index (BMI) on Peak Torque (PT)

<table>
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<th>Source Variable</th>
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<th>Mean Squares</th>
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* p < .05
† p < .01
‡ p < .001

A one-way between-subjects MANCOVA was calculated to examine the effect of stretching protocol on single leg standing broad jumps and peak torque values covarying out the effect of activity level as determined by the activity index score. Activity index scores were significantly related to power and peak torque ($\Lambda_{9,57} = .718$, $p < .05$). Follow-up univariate ANCOVAs indicated that the activity index scores were significantly influenced by the single leg standing broad jump left leg ($F_{1,65} = 10.054$, $p < .01$), single leg standing broad jump right leg ($F_{1,65} = 16.132$, $p < .001$), peak torque left leg at 180°/sec ($F_{1,65} = 4.720$, $p < .05$), peak torque left leg at 300°/sec were ($F_{1,65}$
= 5.651, p < .05), and peak torque right leg at 300°/sec
\((F_{1,65} = 5.070, p < .05)\) (Table 4).

Conclusion: Evidence in this study suggests that a positive relationship occurs between an individual’s activity index score and a) the single leg standing broad jump and b) peak torque values. As activity index scores increase, single leg standing broad jump and peak torque values increase.

Table 4. MANCOVA for Activity Index (AI) on Single Leg Standing Broad Jump (SLSBJ) and Peak Torque (PT)

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</table>

* p < .05
† p < .01
‡ p < .001
DISCUSSION

Discussion of Results

Stretching for the general population of active individuals has been a mainstay in warm-ups and cool-downs during exercise, sport practices, and athletic events. They do this to improve their flexibility and range of motion, as well as prevent them from getting an injury. The truth though is that although stretching does improve flexibility and range of motion, there is no significant proof that stretching decreases the incidence of injury.\textsuperscript{3} 
Still the focus of this study was to look at stretching using two different methods and comparing them to a control group that did not stretch. This was done as one of the stretching methods used, passive static stretching, had shown reductions in power and peak-torque values compared to a control group.\textsuperscript{5-8} The other stretching technique used, proprioceptive neuromuscular facilitation (PNF) hold-relax, was used to see if PNF stretching would yield better results.

It was hypothesized that PNF stretching would show less of a decrease in power and peak torque values compared to passive static stretching. Power was measured by using
a single leg standing broad jump test, while peak torque was measured by the use of a Biodex™ System 3 Multi-Joint Dynamometer. Statistical analysis showed no significant difference between PNF hold-relax and passive static stretching in terms of flexibility, power, and peak torque values at isokinetic speeds of 60°/sec, 180°/sec, and 300°/sec for either leg when compared to a control group.

A study done by Marek et al26 focused on the quadriceps muscle comparing PNF hold-relax and static stretching. Data was collected on peak torque at 60°/sec and 300°/sec, and mean power output. With the better equipped research facilities their research showed similar results in the decreases in strength and power values as this research had found.

Although findings for the hypothesis were found to be insignificant it must be noted that a trend was noted by the researcher. Many subjects that participated in the research had noted that they felt greater gains in flexibility after going through the PNF protocol. Some subjects also made note that they believed they were able to do better during the power tests. These notes that the subjects made were done without the knowledge of what the research was about. With this information in mind future
professions that wish to design stretching protocols for the physically active may want to take this into account.

A factor that must be taken into account in this research is that only one muscle group was stretched. The test used to measure power is multi-jointed and uses multiple muscle groups. The quadriceps muscle group, gluteal muscle group, gastrocnemius and soleus along with the hamstring muscle group all must contract for the body to perform the single leg standing broad jump.

Another factor to consider is in regards to the peak torque measurements taken using the dynamometer. Although the hamstrings are isolated and readings clear, the action of the leg is not placed in a closed-chain position or in functional movement. The information provided however can still be used as a reference point for future studies that wish to pursue the relationship of stretching and strength and power losses.

Looking at the additional finding and analyzing that information the study suggests that a relationship occurs between an individual’s BMI score and peak torque values. The data shows that as BMI increases so does the peak torque values. This could be speculated that individuals who have higher BMI scores may have more muscle mass and therefore able to create higher peak torque values.
Evidence also suggests that a relationship occurs between an individual’s activity index score and the single leg standing broad jump, as well as peak torque values at higher end speeds. This leads to the belief that the more active an individual is the more likely their flexibility, power, and peak torque scores will increase.

The results of this study show that there is no significant difference between PNF hold-relax and static passive stretching in flexibility, power, and peak torque scores. With this information those professions and careers that design exercise programs, more specifically focusing on the stretching, can take this information to figure out what type of stretching technique they wish to use. Knowing that stretching does result in a decrease in power those who are physically active may want to consider stretching after exercise or competition rather than before so that performance does not decrease due to loss in power.

Conclusions

The results of this study discovered the following major conclusions:

1. There was no significant difference in improvement of flexibility between propriocetive neuromuscular
facilitation (PNF) hold-relax stretching and passive static stretching.

2. There was no significant difference in the decrease of power between PNF hold-relax stretching and passive static stretching compared to the control group.

3. There was no significant difference in the decrease of peak torque at the isokinetic speed of 60°/sec between PNF hold-relax stretching and passive static stretching compared to the control group.

4. There was no significant difference in the decrease of peak torque at the isokinetic speed of 180°/sec between PNF hold-relax stretching and passive static stretching compared to the control group.

5. There was no significant difference in the decrease of peak torque at the isokinetic speed of 300°/sec between PNF hold-relax stretching and passive static stretching compared to the control group.

6. There was a significant positive relationship between body mass index and peak torque. This study alludes that better body mass index scores can produce higher peak torque values.

7. There was a significant positive relationship between activity index scores and single leg standing broad jump
scores. This study suggests that more active people can produce more power in a single leg standing broad jump.

8. There was a significant positive relationship between activity index scores and peak torque values at 300°/sec. This study suggests that more active people can produce higher peak torque values at high speeds of isokinetics.

Recommendations

Future studies should examine some of the following to expand upon this research:

1. Expand the research to involve other PNF stretching techniques such as contract-relax and slow reversal contract relax.

2. Expand the research to involve other stretching techniques such as active isolated stretching, neuromuscular stretching, functional stretching, etc.

3. Examine the effect of using different stretching protocols in terms of time.

4. Studies should be conducted involving a long term stretching program.

5. Enhance the research to utilize functional tests when collecting the data.
6. Enhance the testing of the research to encompass other aspects of the body such as speed, agility, and balance.

7. Expand the research to involve other muscle groups in the lower extremity.

8. Explore the relationship between power and strength losses from stretching and athletic performance.
REFERENCES


APPENDICES
Review of the Literature

This review of the literature will go over all literature that has been written which has led to the development of this study: PNF vs. Static Stretching for Power Output, Power Capacity, and Anaerobic Fatigue. In the field of sports medicine proprioceptive neuromuscular facilitation (PNF) and static stretching have always been looked upon as exercises to improve flexibility and range of motion. PNF has also been utilized in the increase of proprioception and neuromuscular system. However there has been the possibility of increasing strength while using PNF exercises. This literature review is divided into three sections: 1) Background Information on PNF, 2) PNF and Strength Studies, and 3) Static Stretching. A summary of the literature will be given at the end of the review.

Background Information on PNF

Proprioceptive neuromuscular facilitation (PNF) exercises are designed to improve proprioception, range of motion, and motor control. The ideas that started PNF exercises were from research done by a group of neurophysiologists who were examining how the muscles were
affected by various proprioceptive stimuli. These ideas were gathered and analyzed by Herman Kabat, MD who laid down the foundations for PNF exercises during the late 1940s into the early 1950s. Kabat was assisted by Margaret Knott, PT, who would further advance PNF with the development of movement patterns, techniques, and lay down the principles of PNF in the late 1960s with the assistance of Dorothy Voss. These exercises, due to their ability to improve muscular control, were first utilized in a rehabilitative setting for those suffering from disease that attacked the neuromuscular system or severe injuries to the musculoskeletal system. With the results that the exercises were giving, the techniques gradually found use in orthopedic settings as they improved flexibility, strength, and proprioception of injured muscles and joints.

As to why such improvements occur in these areas is still up to debate between two major theories: neuromuscular modification and viscoelastic theories. The neuromuscular modification theory states three points as to explain the gains in flexibility, proprioception, and strength. The first point is that PNF increases the firing threshold of sensory receptors in the joint and muscles resulting in increased range of motion. The next point is the exercises promote further recruitment of alpha motor
neurons, which, with more neurons to control the signals to the muscle, greater force output can be attained. The last point in the theory states that more inhibitory neural stimuli on the stretched muscle is produced. This is done through the contraction of the agonist muscle during the PNF exercise. With this theory understood, a clearer connection can be made between PNF creating muscular improvements towards strength gains. This is especially possible when looking at the second point of the neuromuscular theory.

The second theory, the viscoelastic theory focuses on the muscle, tendon, and fascia complex. By changing the shape of the muscle sheath using isometric contractions or having muscles in an elongated state, the sheath will then alter its shape to conform to the muscle. By continuing this process the sheath will eventually deform to allow greater range of motion since the sheath can now stretch and accommodate to the shape of the stretched muscle. Since contractions must occur to allow for such a deformity to occur the muscle must work to have any affect on the sheath. This theory can also allude to the effects PNF has on muscular strength, power, and force.

An assessment of PNF usage done in 1993 showed an increase in use for rehabilitation when compared to a
similar assessment in 1981.\textsuperscript{5} The theories are but one aspect of PNF that raises the question of strength improvement. However, the subtle rise in use of PNF over time has shown its usefulness in rehabilitation. The result of which has been cases being reported in the use of PNF to rehabilitate athletes from injuries. In 2001, a case study was reported of a female hockey player who had undergone ACL reconstruction and although instability tests were negative, the athlete still complained.\textsuperscript{6} The athlete was then placed on a neuromuscular rehabilitation program with the use of PNF exercises, which after six months she reported no sensation of instability.\textsuperscript{5} Tyler and McHugh\textsuperscript{6} reported:

"Failure of static knee stabilizers can be a cause of instability. Following ACL reconstruction, a neuromuscular rehabilitation program may prevent residual knee instability once the static stabilizers have been restored."\textsuperscript{(p577)}

If the static stabilizers were failing then the dynamic stabilizers would have to work harder to keep the joint intact. If this is the case, it is possible to make a connection between PNF exercises and improvements in strength in the dynamic stabilizers.

Another instance of PNF being used was in a research study utilizing proprioceptive training to prevent ACL injuries in soccer.\textsuperscript{7} Although stated that PNF exercises
were used as a part of the stretching routine in the prevention program, they were not measured on how they affected the knee. This raises a question as to utilizing a technique without quantifying it scientifically. Going back to the case study for a moment the researcher may have used the exercises to stimulate the hamstrings as they are the dynamic stabilizers for the knee working with the ACL which is the static stabilizer.

With the use of PNF being incorporated into stretching programs the debate comes up of how these exercises compare to the traditional static stretches. To first understand either stretching type, a brief explanation needs to be done on golgi tendon organs (GTO).

GTOs are mechanoreceptors in the muscle and tendons that are sensitive to the tension placed on the muscle. If enough tension is placed on the muscle the GTOs would react and send signals to cause a muscular relaxation to the muscle which is receiving tension. If the relaxation occurs in the same muscle of the tension this is known as autogenic inhibition. This can be produced by contracting the muscle right before the muscle is to be stretched. Another form of inhibition known as reciprocal inhibition is cause when the muscle opposite to the muscle being stretched contracts. This tension created by the
contracting muscle can activate the GTOs as well inhibiting muscular contraction in the stretched muscle.⁸

After understanding the theories of PNF, how it is used in rehabilitation and prevention, and how it compares to passive-static stretching, it needs to be understood that there are different techniques in utilizing PNF exercises. The main three techniques used in PNF exercises are Hold-Relax (HR), Slow-Reversal-Hold-Relax (SRHR), and Contract-Relax (CR). Each of these exercises will be broken down into three steps using Holcomb’s approach. First all three exercises initially start with a ten second passive pre-stretch.⁸ Hold-Relax then continues with a six second isometric contraction of the muscle just stretched followed by 30 seconds of passive stretching.⁸ Slow-Reversal-Hold-Relax is similar to Hold-Relax with the difference that during the last part the opposing muscle of the muscle being stretched concentrically contracts.⁸ Finally Contract-Relax follows the pre-stretch by concentrically contracting the muscle just stretched with resistance from a partner through the full range of motion, and this is followed by a 30 second passive stretch.⁸

Also to note, PNF exercises were first developed as partner stretches. In a clinical setting this may work, but can be cumbersome in an athletic setting. This would
be due to constant communication between the partners for proper feedback, and only half the team could be stretched at a time doubling the time used for stretching.\textsuperscript{9} Although all three of the techniques discussed use partners, the HR technique can be done by oneself.\textsuperscript{9} Also the SRHR technique can be utilized in self stretching with the use of a table or towel.\textsuperscript{10}

**PNF and Strength Studies**

With the background information on PNF’s history, theories, techniques, and applications understood a further look can be taken into the studies done involving PNF. Many of these studies look into various aspects of strength as well as flexibility compared to passive static stretching. Starting with older studies working to more current ones will provide better ideas of how the research has progressed over time in regards to PNF. Drawbacks will be noted in each study so that future studies can take steps to correct such limitations.

The first study to be looked upon was done in 1987 which was designed to examine PNF’s affects on hamstring activity and range of motion (ROM).\textsuperscript{11} The first drawback to note from the study was the small sample of only 10 people
collected for this study. From the results of the study the discussion notes that Contract-Relax (CR) and Slow-Reversal-Hold-Relax (SRHR) does not allow muscle relaxation of the muscle being stretched while the muscle opposite to the stretched muscle contracts. However, despite this information ROM increases were found while tension forces acted upon the hamstring.\textsuperscript{11} The study concludes by stating that ROM increases are possible using CR and SRHR techniques. This is followed up by a summary that muscle activation and ROM in relation to PNF exercises is still unclear and that further study is warranted. This study notes the improvements possible in flexibility and ROM using PNF and starts alluding to the affects of PNF on the muscle in terms of strength.

Three years later in 1990 a study was done that looked at how PNF utilizes the proprioceptors of the body by testing peak torque output.\textsuperscript{12} The reliability of this test is more reliable in terms of sample population of 42 subjects compared to the 10 as noted in the previous study. The draw back to this study was that it was only done over a three day period testing each individual’s peak torque output in unilateral extension, unilateral flexion and extension, bilateral extension, and bilateral flexion and extension. Despite the short amount of time to take
readings the study did show increases in peak torque output after each day after a PNF session.\textsuperscript{12}

A year later in 1991 Gabriel and Kroll\textsuperscript{13} did a study on PNF focusing on isometric strength in the elbow. The study finds that among the 20 subjects used that PNF interferes with the muscles in maintaining a maximal effort isometric contraction in elbow flexion compared to an initial baseline. However, despite the findings the study was only done over a four day period and the sample size is relatively small with the 20 subjects divided in half with one group used as a control while the other utilized PNF exercise. Regardless this is one of the earlier studies in this review that focuses more on the strength than the past studies so far reviewed.

The first study in this review to truly look into muscle strength and ROM in relationship to PNF was done in 1992 by Lustig et al.\textsuperscript{14} They took a look at CR and SRHR and how they affected muscle flexibility and strength. Although no significant difference was found in flexibility between the exercises there were increases in ROM. Also in the post test results, of the study, significant increases in strength were also established compared to the control group. As a result the study suggests that PNF has the ability to increase both flexibility and muscular strength.
However, the study notes in a practical setting it is more likely that these exercises would be better at maintaining muscular strength compared to normal strength training exercises. As an alternative these exercises would be beneficial to strength if traditional strength training was contraindicative.¹⁴

The information provided by the study done by Lustig et al.¹⁴ would later be reinforced by Worrell et al.¹⁵ Their study was trying to discover the most effective way of developing hamstring flexibility as well as the effects of improving peak torque in the hamstrings.¹⁵ By using isokinetics to test strength a controlled setting could be used to gain more accurate information of any strength gains that may occur during the study. Despite the small sample size of the study all participants saw an increase in peak torque during eccentric activity and at higher ended speeds of concentric contractions as well. In terms of flexibility, the study showed no significant differences between passive static stretching and PNF, but improvements in flexibility were still noted on average of 21.3% and 25.7% respectively.¹⁵ In closing of the study the researchers made note that further studies needed to be done to explain why there were no gains in strength at low ended speeds of isokinetics. What was also noted by the
researches was that the study was done using open kinetic chain isokinetics and that a study using closed kinetic chain isokinetics should be done to more accurately assess the muscular strength improvements functionally.\textsuperscript{15}

In 2000, Carter et al\textsuperscript{16} studied how PNF affected neuromuscular response of the hamstrings during rapid elongation. Using the subjects, however, still leads to the results that PNF has no affect on the semitendinosus and decreases the biceps femoris in terms of muscle activity for both muscles.\textsuperscript{16} These results were determined by the use of an EMG while the subject performed PNF Contract-Relax exercises. It should be noted though that this study uses a somewhat small sample size of 24 subjects, and the PNF exercises were not done alone during the testing. The exercises were accompanied by what the researchers describe as jerks both before and after the exercise was done before a measurement was taken. Although these jerks were used to measure stretch reflex there is no mention of whether it could have altered the effectiveness of the PNF exercise.

The last two most recent studies in this review of literature were both done in 2002. The first to be discussed is a study that could aid future studies as it was designed to set a baseline of normal values for peak
torque, work, and performance of the shoulder in the D1 and D2 PNF movement patterns of the shoulder.\textsuperscript{17} Although the study looks at the shoulder and PNF movement pattern exercises it does provide values of strength in both concentric and eccentric contractions. It could lead to a future study that looks at the D1 and D2 patterns of the lower extremity as well as setting up baseline normal values. It also offers more support of a possible relationship between PNF and strength.

The final study to be examined done by Kofotolis et al\textsuperscript{18} compared PNF with isokinetics on thigh strength, endurance, and jumping ability. Although the sample size consisted of 24 subjects, the information provided in the study shows stronger support of the relationship between PNF and strength. The research shows that isokinetics proved to be better at improving muscular strength and endurance compared to PNF exercises, the research showed that PNF was equal to isokinetics in improving jumping abilities.\textsuperscript{18}

Static Stretching

Static stretching has been the traditional mainstay of warm-up and increasing flexibility among the general
population of the physically active. To add to the general consensus of gaining flexibility from stretching, Mann and Whedon\textsuperscript{19} note the history of research done indicating the relationship between improved flexibility and decreased risk of injury. Static stretching is divided into two techniques: active stretching and passive stretching.\textsuperscript{20} Active stretching requires the person to move the joint into the position themselves. This uses the antagonistic muscles to contract while stretching the agonist. While on the other hand, passive uses a partner or tool to move the joint without contraction of any muscles. This allows for relaxation to assist in the stretching of the muscles. However, the immediate benefits of stretching only improve flexibility for 20-90 minutes depending on the person during a single session of stretching.\textsuperscript{21}

Although the benefits of stretching improve ROM and flexibility they also seem to decrease other aspects of the muscle according to several recent studies. One study examined the effects of static stretching on balance and proprioception of the lower extremity.\textsuperscript{22} The results indicated that during acute bouts of static stretching balance and proprioception decreased compared to the control group. However, this could be due to the desensitizing of the neuromusculature being overstretched.
This being said a study done by Halbertsma et al\textsuperscript{23} suggests that a single bout of static stretching does not increase ROM. Instead stating that ROM is increased from the muscle’s stretching tolerance improving. With Halbertsma’s study in mind, Perle\textsuperscript{24} looked at the immediate effects of acute stretching and found little significance in improvements in range of motion and flexibility.

On the other hand the use of static stretching over a long period of time does have its benefits to ROM and flexibility. Chan et al\textsuperscript{25} notes in their study that the effects of static stretching programs using various setups still increase ROM and flexibility over time regardless of protocols. Further strengthening the benefits of static stretching in long term improvements of ROM and flexibility is a study done by Young and Elliott.\textsuperscript{26} Their study notes that static stretching in the long term does improve ROM and flexibility. However, acute bouts of stretching were noted to decrease muscular performance especially in acute bouts of muscular activity.\textsuperscript{26}

Cramer et al\textsuperscript{27} would be able to elaborate better on the decreases in strength, when they examined the effect of static stretching on concentric isokinetic extension of the lower extremity. By using peak torque as measurement, the study noted that static stretching could be detrimental to
high intensity sports. This would be in part due to the decrease in strength from the static stretching.\textsuperscript{27} Power et al\textsuperscript{28} took a more functional as well as a closed kinetic chain approach as well, using three jumping tests and electromyography (EMG) to record muscular activity. The study noted the increase in ROM as hypothesized, but only found a decrease in force production and little change in jumping performance.\textsuperscript{28} In examining only the relationship between static stretching and jump performance, McNeal and Williams\textsuperscript{29} looked at adolescent female gymnasts in acute stretching sessions. Their study showed a decrease in power and strength in the lower extremities that were being stretched.\textsuperscript{29} Reducing performance in exercise that required massive quick bursts of force, such as vaulting. To best summarize the reasoning of why static stretches decrease strength and force production the study done by Behm et al\textsuperscript{30} gives a good explanation. The research notes that static stretching inhibits maximal voluntary contraction forces resulting in an increase in muscular inactivation. This increase inactivation is due to the muscles just being lengthened and stretched so that they can not recover in time to contract and produce force.
Summary

There are various perspectives on PNF from theories of how it works, to techniques on how to perform the exercises, and whether or not the exercise can be done alone or not. Regardless of the variety surrounding the PNF exercises there is a possible relationship between improvements in flexibility, ROM, strength, and proprioception when using these exercises.

In review of the studies that have been examined in this review of literature it is noted that many of the studies have small sample sizes usually fewer than 30 subjects. Overall although there was no significant difference in flexibility between PNF and passive static stretching an improvement was noted. Also many of these studies indicate muscular strength gains when utilizing PNF exercises despite some studies showing the contrary.

In looking at static stretching the benefits of increased ROM and flexibility can not be denied, especially since they aid in decrease chances of injury. However, from looking at past research it suggests that static stretching should be done with long term goals in mind. Also precautions should be taken to avoid static stretching
before activities that require a high demand of force production on the muscles.
APPENDIX B

The Problem
Statement of the Problem

Studies on static stretching and proprioceptive neuromuscular facilitation (PNF) have each shown a relationship between static stretching and an improvement in range of motion and flexibility. The purpose of this study was to determine if a difference occurs between PNF stretching versus static stretching on the performance of flexibility, peak torque, and power in the hamstring muscle group.

Definition of Terms

The following are the definition of terms that are relevant to this research:

1. Concentric contraction - is when the muscle contracts while shortening.
2. Dynamometer - an apparatus for measuring force or power.
3. Flexibility - the ability of a joint to move freely through its full range of motion.
4. Isokinetic - using a fixed speed and accommodating resistance to provide maximal resistance throughout the range of motion.
5. Isometric – a contracting muscle held fixed so that contraction produces increased tension at a constant overall length.

6. Modified Sit and Reach – measure the flexibility of the muscles in the back and legs.

7. Peak Torque – The allowable peak torque applied to the output shaft when normally started from a stop or normally stopped from a running mode.

8. Physically Active – Physical activity consists of athletic, recreational or occupational activities that require physical skills and utilize strength, power, endurance, speed, flexibility, range of motion, or agility.


10. Proprioceptive Neuromuscular Facilitation (PNF) – techniques used to improve motor skills through positive motor transfer, using the principles of facilitation/inhibition; irradiation/reinforcement; reciprocal innervations.

11. PNF Hold-Relax – a form of PNF stretching consisting of a passive pre-stretch, followed by a isometric contraction, finished with a passive post stretch.
12. Range of Motion (ROM) – range through which a joint can be moved.

13. Single Leg Standing Broad Jump – participants jumping mechanics will consist of the following: subjects will jump off and land with the same leg.

**Basic Assumptions**

The following assumptions will be made when conducting this research:

1. The PNF hold-relax and passive-static stretching exercises used are performed correctly.

2. The data collected from the modified sit and reach, Biodex™ System 3 Multi-Joint Dynamometer, and single leg standing broad jump test for each session is accurate.

3. The subjects will have not done any other flexibility exercises during the research.

4. All tests are valid and reliable

**Limitations of the Study**

The following are limitations of the study:

1. Only physically active college age students will be included in this study.
2. Subjects will be gathered from the campus of California University of Pennsylvania only, so potential subjects who are not students or student athletes will be unavailable reducing sample size.

Significance of the Study

Athletes have always used stretching as apart of their warm-up and cool-down routines. With research implying that traditional static stretching improves flexibility and range of motion. However research has shown no significant relationship that stretching will reduce incidence of injury\textsuperscript{3}. Unfortunately according to the research static stretching although improves flexibility and range of motion, has suggested that strength and power decreases in the muscle that is stretched\textsuperscript{5-8}.

Proprioceptive neuromuscular facilitative (PNF) stretching has also suggested that the technique improves flexibility.\textsuperscript{9} In terms of strength and power the research has been controversial suggesting both increases and decreases.\textsuperscript{10-12} The significance of this study is to compare the two stretching techniques in comparing PNF with static stretching. Many studies have been done examining both static stretching and PNF individually, but few studies have been performed comparing the two techniques.\textsuperscript{5,7,10} This
study will go further by comparing the two stretching techniques and adding in a control group to compare to. The study will also attempt to use a much larger sample size compared to past research reviewed by this study. Also this study will look at peak torque and power to compare which past research reviewed looked independently of one another. Flexibility will also be looked at in the research to keep high validity to the study to show that stretching protocols were performed accurately and correctly.

This research is important in that it will allow for future changes in warm up exercises. So that decreases in strength and power does not occur after the warm-ups during practices or competitions. With the use of PNF the researcher hopes to show that PNF stretching will still give the benefits of improving flexibility and range of motion while not having the negative effects of decreasing strength and instead improve strength and power in the muscle stretched.
APPENDIX C

Additional Methods
APPENDIX C1

Informed Consent Form
Informed-Consent Form

1. “John N. Wen, who is a graduate student in the athletic training program at California University of Pennsylvania, has requested my participation in a research study at this institution. The title of the research is PNF vs. Static Stretching of the Hamstring muscle group for Flexibility, Peak Torque, and Power.”

2. “I have been informed that the purpose of the research is to. "Compare the differences between PNF vs. static stretches looking at improvement in flexibility, peak torque, and power.

3. "My participation will involve performing a warm up followed by a randomly selected stretching protocol, and then be tested by a sit and reach test, Biodex™ System 3, and a single leg broad jump. This will be done at least four times first for familiarization, and one each for the other protocols. There will also be at least 24 hours in between each day of testing for rest and recovery.”

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 muscle soreness from performing isokinetics which the researcher will allow a rest period for recovery, a spotter during the single leg broad jump to reduce the chances of a dangerous fall.”

5. "I understand that in case of injury I can expect to receive treatment or care in Hamer Hall’s Athletic Training Facility which will provided by the student researcher, John N. Wen, or another Certified Athletic Trainer, either of which whom can administer emergency and rehabilitative care. Additional services needed for prolonged care past 3 days will be referred to the attending physician at the Downey Garofola Health Center located on campus.”

6. “There are no feasible alternative procedures available for this study.”

7. "I understand that the possible benefits of my participation in the research are an increase in hamstring flexibility, providing additional information to existing research, and allow for a better understanding between PNF vs. static stretching in the relationship with peak torque and power.”

8. "I understand that the results of the research study may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my records, John N. Wen will maintain all documents in a secure location in which only the student researcher and research advisor can access. Confidentiality will be maintained by replacing name’s of the subjects with an identification number instead.”

9. "I have been informed that I will not be compensated for my participation."

10. “I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by John N. Wen, wen5917@cup.edu, 265 California Rd., Apt 524B, Brownsville, PA 15471, (571) 228-6578, and Dr. Carol Biddington, EdD, biddington@cup.edu.

11. “I understand that written responses may be used in quotations for publication but my identity will remain anonymous.”
12. "I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request."

Subject's signature__________________________________________ Date ________________
Other signature (if appropriate) ________________________________ Date ________________

13. "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 research study, have answered any questions that have been raised, and have witnessed the above signature."

14. "I have provided the subject/participant a copy of this signed consent document if requested."

Investigator’s signature______________________________________ Date ________________

Approved by the California University of Pennsylvania IRB
APPENDIX C2

Activity Index
Part I. Medical Clearance

In general, if you are under 40 (men) or 50 (women) years of age, have no physical complaints, and have had a medical checkup within the past 2 years, it is probably safe for you to begin an exercise program at your current level of physical activity and gradually increase it. To determine whether you need to consult your physician, read the following list of statements and check any that are true for you.

___ I am not feeling well.
___ I have a specific health concern.
___ I am over 20% above my desirable weight and much of the excess is body fat.
___ I have been sedentary for a long time.
___ I have a history of cardiovascular disease.
___ I can’t walk more than 2 miles.
___ I have one or more of the following symptoms after exertion:
   ___ Chest pain
   ___ Dizziness or faintness
   ___ Gastrointestinal upset
   ___ Difficulty breathing
   ___ Shortness of breath for more than 10 minutes after exertion
   ___ Lingering fatigue and difficulty in sleeping

___ I have a history of coronary heart disease risk factors:
   ___ Diabetes
   ___ Hypertension
   ___ High blood cholesterol levels
   ___ Cigarette smoking
   ___ A blood relative who had a heart attack before age 60

If you checked on or more of these statements, you should consult your physician before beginning an exercise program.

Part II. Calculate Your Activity Index

1. Frequency: How often do you exercise?
   If you exercise: Your frequency score is:
   Less than 1 time a week 0
   1 time a week 1
   2 times a week 2
   3 times a week 3
   4 times a week 4
   5 or more times a week 5

2. Duration: How long do you exercise?
   If each session continues for: Your duration score is:
   Less than 5 minutes 0
   5 to 14 minutes 1
   15 to 29 minutes 2
   30 to 44 minutes 3
   45 to 59 minutes 4
   60 minutes or more 5
3. Intensity: How hard do you exercise?

<table>
<thead>
<tr>
<th>If exercise results in:</th>
<th>Your intensity score is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change in pulse from resting level</td>
<td>0</td>
</tr>
<tr>
<td>Little change in pulse from resting level</td>
<td>1</td>
</tr>
<tr>
<td>(slow walking, bowling, yoga)</td>
<td></td>
</tr>
<tr>
<td>Slight increase in pulse and breathing</td>
<td>2</td>
</tr>
<tr>
<td>(table tennis, active golf with no golf cart)</td>
<td></td>
</tr>
<tr>
<td>Moderate increase in pulse and breathing</td>
<td>3</td>
</tr>
<tr>
<td>(leisurely bicycling, easy continuous swimming, rapid walking)</td>
<td></td>
</tr>
<tr>
<td>Intermittent heavy breathing and sweating</td>
<td>4</td>
</tr>
<tr>
<td>(tennis singles, basketball, squash)</td>
<td></td>
</tr>
<tr>
<td>Sustained heavy breathing and sweating</td>
<td>5</td>
</tr>
<tr>
<td>(jogging, cross-country skiing, rope skipping)</td>
<td></td>
</tr>
</tbody>
</table>

To calculate your activity index, multiply your three scores:

Frequency ___ X Duration ___ X Intensity ___ = Activity index ___

To assess your activity index, refer to the following table:

<table>
<thead>
<tr>
<th>If your activity index is:</th>
<th>Your estimated level of activity is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 15</td>
<td>Sedentary</td>
</tr>
<tr>
<td>15 – 24</td>
<td>Low active</td>
</tr>
<tr>
<td>25 – 40</td>
<td>Moderate Active</td>
</tr>
<tr>
<td>41 – 60</td>
<td>Active</td>
</tr>
<tr>
<td>Over 60</td>
<td>High active</td>
</tr>
</tbody>
</table>

If your activity level is in one of the lower categories, review the components of your score, (frequency, duration, intensity) to see how you can raise your score. Add to your current exercise program or devise a new one.
APPENDIX C3

Data Collection Form
Subject Identification Number: ____________________________

Height: ____________ Age: ____________

Weight: ____________ Sex: ____________

Have you had an injury or surgery to the hip, knee, and/or ankle within the past year? YES / NO

Proprioceptive Neuromuscular Facilitation Protocol

<table>
<thead>
<tr>
<th>TEST</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Sit and Reach (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Leg Standing Broad Jump Test (cm)</td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Peak Torque Speeds (N-m)</td>
<td>60°/second</td>
<td>180°/second</td>
<td>300°/second</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

Static Stretching Protocol

<table>
<thead>
<tr>
<th>TEST</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Sit and Reach (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Leg Standing Broad Jump Test (cm)</td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Peak Torque Speeds (N-m)</td>
<td>60°/second</td>
<td>180°/second</td>
<td>300°/second</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>

Control

<table>
<thead>
<tr>
<th>TEST</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Sit and Reach (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Leg Standing Broad Jump Test (cm)</td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Peak Torque Speeds (N-m)</td>
<td>60°/second</td>
<td>180°/second</td>
<td>300°/second</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
</tbody>
</table>
APPENDIX C4

IRB Review Application for
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  Proprioceptive Neuromuscular Facilitation vs. Static Stretching of the Hamstring Muscle Group for Flexibility

Researcher/Project Director  John N. Wen

Phone #  (724) 938-9287  E-mail Address  wen5917@cup.edu

Faculty Sponsor (if required)  Dr. Carol Biddington, PhD

Department  Health, Science, and Sport Studies

Project Dates  February 2005  to  May 2005

Sponsoring Agent (if applicable)

Project to be Conducted at  California University of PA

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://cme.nci.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  ______________________________________________________________________

Approved October 9, 2003
(All Proposals Must be Typed)

1. Give a brief overview of your project/proposal with research hypothesis.

The purpose of this study is to examine the differences between Proprioceptive Neuromuscular Facilitations (PNF) Hold-Relax stretching versus traditional static stretching. Focusing in on the hamstring muscle groups the areas of being examined are flexibility, peak torque, and power using a specific test for each variable being investigated into. The research hypothesis will be that PNF Hold-Relax stretching will yield greater benefits in all of the above variables versus traditional static stretching. With the null hypothesis stating that there will be no difference between the two stretching techniques making improvements to hamstring flexibility, peak torque, and power.

2. Give a brief description of the subjects you plan to use, and check the appropriate box(es) below.

- Adult Volunteers
- Minor Volunteers
- Children Under 18
- CAL University Students
- Minorities
- Disadvantaged
- Mentally Ill
- Elderly
- Mentally Retarded
- Physically Handicapped
- Prisoners
- Pregnant Women

3. Is remuneration involved in your project? ☑ Yes or ☐ No

If yes, Explain below.


Subjects will be selected using the graduate and undergraduate students over the age of 18 in the athletic training program at California University of Pennsylvania. Participation is required of those who have not had any recent injury or surgery to the lower extremity. As well as meeting the requirements of being physically active using an activity index assessment from Insel P, Roth. *Core Concepts of Health, 8th Edition.* New York, NY: Mayfield Publishing; 2000.

5. Does your project involve use of a consent form? ☑ Yes or ☐ No

If yes, attach the form.

See attached form.

6. What instruments or devices will be used to gather data? Provide a copy of documentation pertaining to the data collection, such as but not limited to:

Cover letter, questionnaire/survey, consent form, interview/focus group sheets.

Instruments to be used to collect data will be a goniometer for measuring range of motion (ROM) at the knee joint. The Biodex Multi-Joint System 3 Dynamometer will be used to measure peak torque. A tape measure will be used to record distance traveled in a single leg standing broad jump test. All data collected will be placed on a data collection table. Each subject will have their own data collection table and names will be replaced with an identification number for confidentiality.

7. 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

IRB Proposal Form, Draft-updated 5/1/2002

2
8. Does your project involve the debriefing of those who participated?  
☐ Yes or  ☒ No
If yes, explain the debriefing procedure.

9. The Federal Regulations require that the protocol meet certain criteria before IRB approval can be obtained. Describe in detail how the following requirements will be satisfied:

A. Insure that the risks of the subject are minimized.
B. Justify the degree of risk involved (if any) in relationship to the potential of the project to the subject matter.
C. Insure that the selection of the subjects is equitable.
D. Guarantee that informed consent will be obtained for each prospective subject or the subject’s legally authorized representative and that consent forms will be adequately documented.
E. Monitor the data collected to ensure the safety of the subject.
F. Protect the privacy of subjects and maintain the confidentiality of data.
G. Provide for extra safeguards to protect the rights and welfare of “vulnerable” subjects (e.g., children, prisoners, pregnant women, mentally disabled persons or economically or educationally disadvantaged persons).

Risks will be minimized by having a spotter present when the single leg broad jump is performed. The Biodex System 3 has built in safety features such as a subject controlled stop button to halt the test at any point the subject may feel any discomfort. There are no foreseeable risks involving the use of a goniometer for taking measurements.

There is no foreseeable degree of risk to the subject in relationship to the potential of the project to the subject matter.

Selection of subjects will be equitable to those able to participate in the research. Only those who have had a past recent injury or surgery to the lower extremity will be excluded for reason’s of the research investigating healthy populations.

Informed consent will be given before potential subjects are subjected to any part of the research and that subjects will have a copy of the informed consent form for their own personal records. The researcher will also have the signed informed consent form from the subject in a secure location.

The researcher will be present throughout the research to monitor the testing and ensure subject safety.

Any personal information collected will be located in a secure location and names will be replaced with an identification code instead to ensure confidentiality of the subject.

Vulnerable subjects will not be used in the research so there will be no extra safe guards will be used for any foreseeable problems involving these populations.

Project Director’s Certification
Program Involving HUMAN SUBJECTS

The proposed investigation (research or training program) involves the use of human subjects and I am submitting the complete application form and description of the project to the Institutional Review Board for Research 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 advise of the Board whenever I believe such advice is necessary would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board designed 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 IRB Proposal Form, Draft-updated 5/1/2002
policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

Signature of Project Director

Signature of Department Chairperson

Student Research

Signature of Student Researcher

Signature of Faculty Member

Signature of Department Chairperson

**********

ACTION OF REVIEW BOARD

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.

BOARD DISPOSITION:

Chairperson, Institutional Review Board

Date

3/17/05
REFERENCES


ABSTRACT

TITLE: Proprioceptive Neuromuscular Facilitation vs Static Stretching of the Hamstring Muscle Group for Flexibility, Peak Torque, and Power

RESEARCHER: John N. Wen

ADVISOR: Dr. Carol M. Biddington

PURPOSE: The purpose of this study was to compare proprioceptive neuromuscular facilitation hold-relax stretching to passive static stretching and a control group to the hamstring muscle group examining aspects of flexibility, power, and peak torque.

METHODS: There were 23 physically active college students used for this study, using three separate stretching protocols for the hamstring muscle group: proprioceptive neuromuscular facilitation hold-relax stretching, passive static stretching, and a control protocol. A modified sit and reach was used to test flexibility, single leg standing broad jump was used to test power of each leg, and a Biodex™ System 3 Multi-Joint Dynamometer was used to measure peak torque values of each leg at 60°/sec, 180°/sec, and 300°/sec.

FINDINGS: There were no significant differences in flexibility, power, or peak torque in the hamstring muscle groups between proprioceptive neuromuscular facilitation hold-relax stretching and passive static stretching.

SUMMARY: Populations which utilize stretching in their daily routine should not be overly concerned as to which stretching technique to use when creating a warm-up or cool-down program for their athletes, patients, or clientele since the differences between the two stretching techniques are insignificant.