THE EFFECTS OF PNF STRETCHING ON THE AGILITY OF HIGH SCHOOL ATHLETES

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Brett Piper

Research Advisor, Dr. Robert Kane

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CALIFORNIA, PA

THESIS APPROVAL

Graduate Athletic Training Education

We hereby approve the Thesis of

Brett Piper
Candidate for the degree of Master of Science

Date	Faculty
4-24-09	Robert Kane EdD PT, ATC (Chairperson)
4-23-09	Bruce D. Barnhart EdD, ATC, PTA
4-23-09	Brian Oddi MS, CPT, PES, CSCS

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INTRODUCTION

In several competitive sports, a key component of a successful athlete is the athlete’s agility; the ability to stop, change direction, and attain full speed again as quickly as possible while sometimes moving laterally. Improving this skill is a priority for coaches and athletes alike. One possible mode of improvement could lie in an activity almost every athlete performs, stretching. There are several stretching techniques that have shown to be beneficial in different settings. Specifically, Proprioceptive Neuromuscular Facilitation (PNF) is a type of stretching where research in certain areas of performance is lacking. In addition, understanding the anatomy of stretching is key to grasping how stretching can be beneficial to different measures of performance.

Muscular organelles called Golgi Tendon Organs (GTOs) and muscle spindles are the target of stretching techniques, specifically PNF. GTOs are activated by tension in a muscle. If too much tension is placed on a muscle, the GTOs will send a signal directly to the brain and stimulate relaxation preventing the muscle from being overworked and possibly causing injury [1, 2].

Muscle spindles perform the opposite function. They respond to a muscle being overly stretched and will stimulate a contraction in response. PNF stretching is thought to target these structures specifically; inhibiting muscle spindles and increasing GTO activity allowing a muscle to stretch farther [1,2].

Several Theories exist that attempt to explain the mechanisms by how PNF stretching can increase ROM and therefore improve performance. The main theories are Autogenic Inhibition and Reciprocal Inhibition (see Figures 1 and 2). These theories were recounted by Sharman et al[1]. Autogenic Inhibition is a reduction in the excitability of a stretched muscle that is being contracted.

Figure 1. Autogenic Inhibition [1].

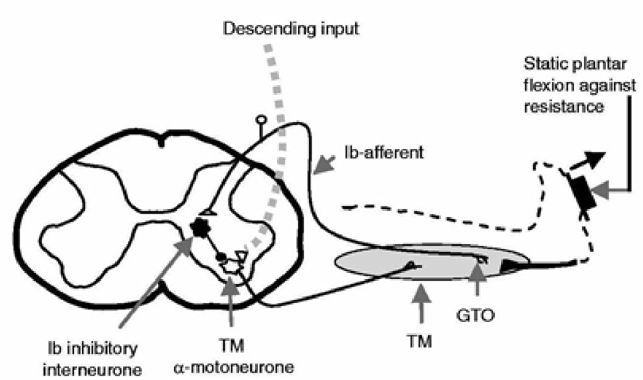


Fig. 1. The mechanism by which autogenic inhibition is purported to contribute to proprioceptive neuromuscular facilitation efficacy. A voluntary static plantar flexion is performed against resistance while the musculotendinous unit (MTU) is on stretch. The plantar flexion developed via descending drive and the existing level of MTU stretch result in an increased firing of tension-sensing mechanoreceptors (Golgi tendon organs [GTOs]) within the same muscle. Increased inhibition from Ib-inhibitory interneurones, a result of the amplified GTO input, results in a reduced level of excitability of the homonymous target muscle (TM), thereby facilitating additional stretch.

Reciprocal Inhibition is a similar process but results in reduced excitability in a stretched muscle when its opposing muscle is contracted.

Figure 2. Reciprocal Inhibition [1].

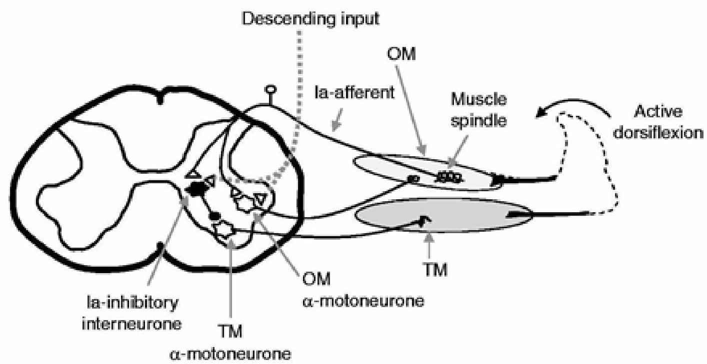


Fig. 2. The mechanism by which reciprocal inhibition is purported to contribute to proprioceptive neuromuscular facilitation efficacy. A shortening contraction of the dorsiflexors (the opposing muscles [OM]) results from descending input onto the OM α-motoneurone. In addition to exciting the OM, descending input and the OM Ia-afferent branch to excite the Ia inhibitory motoneurone. The consequent inhibitory input onto the target muscle (TM) α-motoneurone reduces the activation levels within the same muscle, thereby facilitating additional stretch.

Autogenic inhibition may not be correct however as several researchers have found evidence that supports alternate theories. Moore[3] explored these theories and applied them to the professional dance setting. She also proposed that signals from GTOs may reach the cerebral cortex in the brain and autogenic inhibition may be incorrect. Chalmers conducted two separate studies researching the role of GTOs in the muscle. Chalmers [4,5] also found evidence that autogenic inhibition may be decreased in regards to force production at a muscle. He also found evidence that relaxation of a muscle with stretching may be due to inhibition of the muscle spindle only rather than the activation of GTOs as originally thought. It is the actions on these organelles that lead to increased flexibility and ROM.

Stretching techniques have also been studied extensively in regards to their effect on flexibility and Range of Motion (ROM) including studies that involved PNF. Marek et al [6] conducted two separate studies that compared PNF and static stretching and their effect on several areas including flexibility of the hamstrings. Among other results, the authors found that both PNF and static stretching significantly increased active range of motion (AROM) and passive range of motion (PROM).

Mitchell et al [7] in 2007 looked at the maximal stretch force that could be applied to a person with tight hamstrings. Both PNF and static stretching were used on the subjects. PNF lead to increased stretch that could be applied as compared to static stretching.

Stretching's effect on strength has also been researched extensively. In this case, stretching was found to be more of a detriment than beneficial. Weerapong et al[8] compared static, dynamic, and PNF stretching. In addition to measuring ROM, the researchers also measured strength.

Their results showed no significant changes in their subjects' strength. A study done by Marek [6] et al on PNF also examined stretching's effect on strength. In both studies, the PNF interventions caused significant decreases in the subjects peak torque, mean power output, and EMG amplitude.

Two measures of performance where stretching research is lacking are its effects on speed and agility. Fletcher and Anness[9] studied the effects of several stretching protocols and their effects on fifty meter sprint times. Only one protocol showed a significant change. A static, passive stretch combined with an active, dynamic stretch produced significantly slower sprint times.

Nelson et al[10] examined the effects of three different static stretches compared to no stretching in twenty yard sprint times of sixteen division one college track athletes. Once a week a different stretch was given and measure were taken. With each of the three stretches, results showed a significant increase in sprint times compared to no stretching revealing a decrease in performance.

Finally, research on stretching's effect on agility has received very little research. This gave the researcher the motivation to perform this study. Oakley[11] explored static and dynamic stretching and its effect on T-test times, a measure of agility that requires sprinting, shuffling, and backpedaling. Both stretching interventions showed significantly lower T-test times compared to control with the dynamic stretching group showing significantly lower times than the static stretching group. Faigenbaum[12] also conducted a study with children. This study also examined different warm-up protocols' effect on several measures including agility. The protocols included five minutes of walking followed by five minutes of static stretching, ten minutes of dynamic exercise, or ten minutes of dynamic exercise plus three drop jumps from a fifteen centimeter box. Results revealed a significant decrease in agility measures with five minutes of walking with five minutes of static stretching compared to the ten minutes of exercise with three drop jumps measures.

The effects of stretching have been researched in nearly every measure of performance. Stretching's effect on Range of Motion has been researched extensively with results consistently showing a significant increase in subjects' ROM after every stretching protocol. Stretching also appears to be detrimental to strength measures. However, there are still areas where research is lacking. Specifically, PNF techniques need more research in the area of agility. These techniques need to be examined to determine if they can be beneficial to an athlete’s agility.

METHODS

The Methods Section explains how the research was conducted as well as information about the subjects and instruments used. The following sections are included: Research Design, Subjects, Pilot Research, Procedures, Instruments, Hypotheses, and Data Analysis.

Research Design

A repeated measures, within subject design was used in this study. Subjects served as their own control. The independent variable was stretching (which contained three levels: “No Stretching”, “PNF Hold-Relax,” and “PNF Contract-Relax”) and gender. The dependent variable was the subjects’ agility test times. Times were taken to the hundredth of a second. Each subject completed agility tests after both stretching protocols as well as a control trial. The order in which subjects received the stretching protocols or control was randomized.

Subjects

Subjects used in this study (N=30) were male and female high school athletes attending Burgettstown High School. No subjects with any lower extremity injuries in the prior 3 months were included. As most subjects were minors, both the subjects and their parent/guardian completed Informed Consent Forms (Appendix C1). Consent was also obtained from the Burgettstown Athletic Director and Principal (Appendix C2). To control for possible injury and/or fatigue, none of the subjects used were in season of their respective sports.

Pilot Research

Prior to conducting the research on the intended subjects, a short pilot study was completed on three California University Graduate Assistant Athletic Trainers. This was to familiarize the researcher with the testing procedures and equipment used in this study. Pilot research was also done to determine any problems that may have been present in the procedures. Subjects in the pilot also completed informed consent forms (Appendix C1). After the pilot research was conducted, the researcher decided no changes were needed to the testing procedures.

Procedures

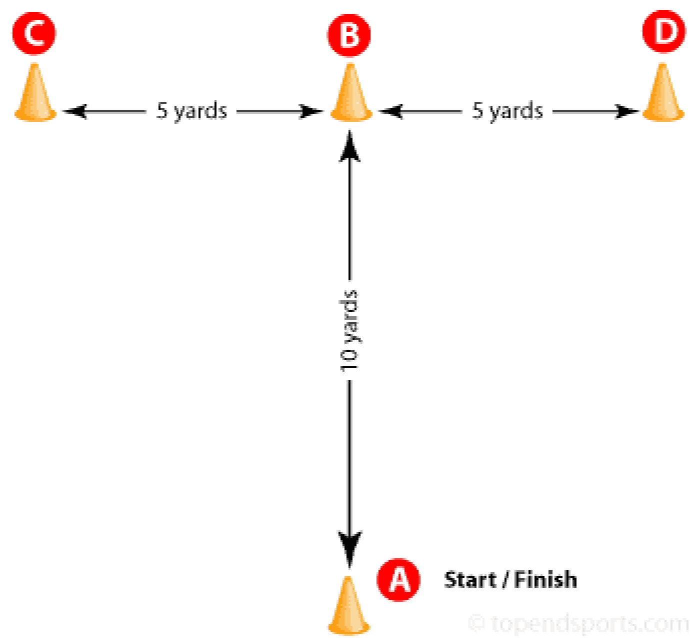
This study was approved by the Institutional Review Board (IRB) at California University of Pennsylvania (Appendix C3). The researcher was granted permission to perform this study at Burgettstown High School and ask its students for participation by the Burgettstown High School Athletic Director and Principal (Appendix C2). Athletes who were not currently in season at Burgettstown High School were asked to participate in this study by the researcher. Each subject signed an informed consent/assent form and/or their parent/guardian signed informed consent/assent forms if they were a minor. Each subject and parents/guardians were also informed of the procedures and potential risks of the study and was given the option to drop out at any time.

To begin the study, each subject was asked to select one of six cards placed face down on a table. The cards contained each potential order of receiving interventions and a control trial. This was to randomize the order of interventions as well as potentially minimize learning effects. Subjects also completed Demographic Information Sheets (Appendix C4) and the researcher recorded each completed trial on an Individual Data Collection Sheet (Appendix C5).

Each trial was performed in the Burgettstown High School gymnasium. To measure subjects' agility, the T-Test for agility was used[13]. According to standard T-Test protocols (Figure 3), four cones were placed in a "T" formation on the floor labeled A-D. Cones A and B were placed ten yards apart. Cones C and D were placed five yards apart to the left and right of Cone B.

Subjects were then informed of the proper procedure for running a T Test for agility. Subjects start at Cone A and sprint forward to Cone B and touch it with their favored hand. Upon completing this, subjects were to then shuffle, without crossing their legs to Cone C and touch it with their favored hand. Next, subjects shuffled from C to Cone D and touched it. Next, subjects shuffled from Cone D back to Cone B and executed a final touch at this cone. Upon completion of the final touch at Cone B, subjects backpedaled to their original starting point of Cone A to finish the test.

Figure 3. T-Test Diagram [13].



The three recorded trials were performed over the course of 3 days with one trial being performed each day. The control trials were performed without warm-up of any kind. Due to their key involvement in the actions of sprinting and quickly changing direction, the quadriceps and hamstring muscles of both legs were stretched for both PNF stretching trials. For the Contract-Relax trials, the hamstring muscles were stretched with the subjects lying supine. The knee of the leg being stretched was kept in full extension. The degree of hip flexion needed to gently stretch the hamstrings varied from subject to subject but was always near ninety degrees (Appendix C6). The opposite leg was also kept flat by the researcher’s leg. The hamstring was stretched for thirty seconds. After ten seconds the patient was asked to concentrically contract the quadriceps with a “Push” command from the researcher. The contraction was held for four seconds after which the subject was told to “Relax” and release the contraction. For Hold-Relax stretching of the hamstrings, the procedure was the same except for one difference. Instead of a concentric contraction, the subject would be asked to contract isometrically and the command “Hold” was used to start contractions.

For the quadriceps muscles, the subjects were asked to lay prone. The knee was flexed to 120 degrees or until the foot contacted the gluteus muscles. An additional stretch was provided by the researcher grabbing the foot with one hand and the knee with the other. The researcher then lifted the knee off the ground until a comfortable stretch was felt (Appendix C6). The stretch was then held for ten seconds. For Contract-Relax stretching, the subject was asked to extend the knee and push the knee back toward the ground for a concentric contraction for four seconds. For Hold-Relax, the stretching protocol was the same except the muscles were contracted isometrically and the command “Hold” was used by the researcher. In the case of both muscles, each stretching protocol was performed three times on each muscle bilaterally. After being stretched, each subject performed a T Test measured to the hundredth of a second. Times were taken by the researcher. For consistent timing procedures, the researcher stood at the start/finish line, out of the way of the subjects.

Instruments

Several instruments were used to assist the researcher in completing this study. Four orange cones provided by Burgettstown High School were used to mark the distances needed to perform the T Test. To measure those distances, a Stanley 30’ tape measure was used. Johnson & Johnson athletic tape was used to mark the floor of the gymnasium where the cones had been after they had been removed after a day of testing. To time the subjects’ T Test times, a Speed Trap II Timer was used. This device a touch pad to start a timer and two infrared “eyes” to stop the timer making if more reliable than a stopwatch as it eliminates human error.

Hypothesis

One hypothesis was tested on the data from this research.

1. PNF stretching will cause significantly lower agility test times compared to a control trial.

Data Analysis

The level of significance for all statistical tests used in this study was set at $\alpha=0.05$. To test the hypothesis, a Repeated Measures Analysis of Variance (ANOVA) was performed using the SPSS 16.0 computer software. The Tukey statistical test was used post-hoc to determine where differences occurred if applicable.

RESULTS

The purpose of this study was to examine the effects of the PNF stretching techniques “Hold-Relax” and “Contract-Relax” on the agility of high school athletes as measured by the T-Test for agility. Subjects performed three trials of the T-Test. One trial was performed with no stretching and served as the control. The other two trials were performed with each of the PNF stretching techniques listed above. This results section is divided into three sections: Demographic Information, Hypothesis Testing, and Additional Findings.

Demographic Information

Subjects used in this study (N=30) were volunteers from Burgettstown High School in Burgettstown, Pennsylvania. Each subject was a participant in at least one sport and remained physically active in the off-season. The subjects age ranged from 14-18 (15.77 ± 1.38). Fifteen subjects were male while the remaining fifteen were female. The subjects’ “Primary Sports” (the sport they listed as being the one they spent the most time in preparation both in-season and off-season) listed were football (n=14), baseball (n=1), softball (n=8), track and field (n=2), and volleyball (n=5).

Hypothesis Testing

Hypothesis Testing was performed on the data using SPSS software. All subjects were tested for agility following both stretching interventions as well as a control trial. All three trials were compared with an alpha level of 0.05.

Hypothesis 1: PNF stretching will cause significantly lower agility test times compared to a control trial.

Conclusion: To test the Hypothesis, mean scores of the Control trials, Hold-relax and Contract-relax trials were calculated for both the male and female participants. A Repeated Measures ANOVA was performed to compare the trial times for the subjects under three conditions: Control, Contract-Relax, and Hold-Relax. Table 1 illustrates the results of the ANOVA. No significant difference was found ($F_{2,56} = .046$ $p > .05$) The test revealed no significant differences among Control (11.63 ± 1.41), Hold-Relax (11.59

± 1.31), and Contract-Relax (11.64 ± 1.36) agility test times. Therefore, the hypothesis was not supported.

Table 1. Repeated Measures ANOVA.

Source	***Type II Sum of Squares***	***DF***	***Mean Square***	***F***	***P***
Outcomes – Sphericity Assumed	.045	2	.022	.250	.780
Outcomes * Gender – Sphericity Assumed	.008	2	.004	.046	.955
Error (Outcomes)– Sphericity Assumed	4.997	56	.089		

Additional Findings

In addition to testing the above hypotheses, the researcher also examined if significant differences existed between male and female T-test times under any conditions. Additional testing was done by the researcher to examine this possibility.

Mean times in the T-Test for males and females under all three conditions can be seen in Table 1. The Repeated measures ANOVA used to test the above hypotheses was done to also test the differences in all T-Test trials according to gender. Males had significantly faster T-test times (10.58 ± 0.69) compared to the female T-test times (12.66 ± 1.00). Table 2 shows the descriptive statistics of the male subjects. Table 3 shows the descriptive statistics of the female subjects.

Table 2. Male T-Test Descriptive Statistics.

Protcol	***Mean, in seconds***	***Std. Deviation***	***N***	***Range, in seconds***
Control	10.594	.706	15	2.38
Contract-Relax	10.615	.732	15	2.48
Hold-Relax	10.544	.664	15	2.45
Total	10.580	.686	45	2.69

Table 3. Female T-Test Descriptive Statistics.

Protocol	***Mean, in seconds***	***Std. Deviation***	***N***	***Range, in seconds***
Control	12.675	1.139	15	4.62
Contract-Relax	12.661	1.032	15	2.62
Hold-Relax	12.634	.890	15	3.47
Total	12.657	1.002	45	4.62

The results of the Repeated Measures ANOVA comparing gender are shown below in Table 4. In each of the three conditions, Control, Contract-Relax, and Hold-Relax, significant differences were found with the males having significantly lower times.

Table 4. Between-Subjects Effects.

Source	***Type III Sum of Squares***	***DF***	***Mean Square***	***F***	***P***
Intercept	12153.126	1	12153.126	5686.626	.000
Gender	96.638	1	96.638	45.218	.000
Error	59.840	28	2.137		

DISCUSSION

To discuss the results found in this study, the following sections will be included: Discussion of Results, Conclusions, and Recommendations for Future Research.

Discussion of Results

The purpose of this study was to determine if the PNF stretching techniques Contract-relax and Hold-relax caused significant changes in the agility of high school aged athletes. Past studies have shown that stretching can be beneficial to an athlete's agility [11]. The researcher wanted to see if PNF techniques could also improve agility as well as see if one technique was more effective than the other.

Research into this possibility showed that no significant changes were made in agility test times in response to the two PNF stretching techniques using the selected stretching protocols. The research also showed that PNF stretching does not affect males and females differently as neither stretching protocols showed improvements in the males vs. the females. The research did not support the hypothesis presented by the researcher.

As stated before, there have been studies that examined different stretching protocols and their effect on agility performance tests. However, PNF stretching techniques had not been examined. Although the techniques have been around for some time, PNF stretching has never been examined in the context of agility although other areas of performance have been measured in response to PNF stretching [6, 7, 14-16].

Previous research showed that stretching techniques can lead to improvements in dynamic levels of performance. Oakley found that stretching will significantly decrease subjects' times in the T-test, the same performance measure used in this study [9]. This implies that stretching techniques can be used to improve agility. However, the best protocol to do this has yet to be uncovered.

Fletcher and Anness showed that stretching can also significantly improve sprint speed [11]. This suggests that increasing a person's ROM in the lower extremity is beneficial to that person's lower extremity performance in dynamic physical activity. However, these studies did not incorporate PNF stretching although PNF stretching has also shown to increase ROM measures [6, 7, 14-16]. The researcher believed that PNF stretching could also lead to increased performance levels. However, this study did not yield any significant results. The reason for these results could come from several different areas.

For this study, a relatively short stretching protocol in regards to time compared to previous studies was used. Other studies where significant increases in performance were noted utilized thirty second, static stretch periods with five second contraction periods [6, 7, 14-16]. The researcher incorporated a protocol that used a ten second static stretch period followed by four second contraction periods. This was done for the sake of keeping the protocol short in regards to time. Brevity was important as subjects were high school students. Many were involved in other extra-curricular activities and/or had problems with transportation to and from testing. Subjects simply did not have time to complete a longer stretching protocol. This shortened protocol may have affected the subjects' results.

Also, the processes that PNF stretching takes advantage of, Autogenic Inhibition and Reciprocal Inhibition reduces muscular excitability. While these processes can facilitate additional gains in ROM, it may have made the muscles less efficient in the T-test, blocking any possible improvements.

This theory may coincide with a previous study done by Faigenbaum et al. in 2006. This study also looked at teenage athletes but rather different warm-up protocols' effect on sprint speed. Several different stretching protocols were used but it was found that a static, passive stretch combined with an active, dynamic stretch produced significantly slower sprint times [17]. If this holds true, under different PNF protocols, T-test test may have shown a significant increase indicating a detriment to performance.

Subjects were also asked to come in three days in a row to complete their agility tests. Looking at individual data collection sheets showed that a great percentage of subjects exhibited a "Practice" or "Learning" Effect, meaning that regardless of the order of their stretching interventions, their first trial was their worst while their last trial was their best. The timing of the trials in conjunction with the shortened stretching protocols may have lead to the results found in the research.

Conclusions

According to data collected, PNF stretching seems to have no effect on the agility of high school aged athletes as measured by the T-test. PNF stretching also seems to have no significant effect on either gender group. However, previous research shows that stretching can be beneficial to agility so PNF techniques should not be discarded altogether.

PNF stretching techniques have been utilized for many years and the processes of Autogenic and Reciprocal Inhibition which they utilize are accepted theories in the medical community. Additional stretching may be needed in order for these processes to show an observable effect on performance.

In studies where PNF stretching caused significant improvements in performance, thirty second static stretches with five second contractions were used. This study verified that this protocol is necessary to show improvements as the ten second stretch with a four second contraction protocol used by the researcher was not effective. If athletic trainers, physical therapists, coaches, personal trainers, and others working with athletes want to incorporate PNF stretching into their routines, a longer protocol needs to be used for it to be effective.

Also, male subjects outperformed female subjects in the T-test under any of the three conditions. This is most likely due to basic human anatomy. Males in the study were taller (mean height of 70.8 in. compared to a mean height of 64.8 in. in females) which would lead to an increased stride length and males traditionally have increased lower extremity musculature. This allowed them to perform faster times in the T-test.

Recommendations for Future Research

For future studies, it is recommended that researchers incorporate a stretching protocol that utilizes static stretch periods of at least thirty seconds and contraction periods of at least five seconds. This protocol has been effective in previous studies that looked at other measures of performance and may be effective in regards to agility. It is also recommended that future researchers look at how the stretching may affect agility after a lengthy stretching program. In this study, agility tests were done only after an acute bout of stretching. A previous study done by Winters et al., showed that significant gains in

ROM can be made after a six week stretching program [18]. A PNF stretching program that lasts a similar length of time should be performed to see if the program could affect agility or other measures of performance.

It is also recommended that future researchers focus on individual sports. This study utilized athletes from five different sports. It is recommended that researchers use samples from one sport at a time such as a study that utilizes only football or softball players. This may determine if PNF is effective for only certain sports.

Finally, the researcher recommends that future studies examine athletes of different age groups and/or ability levels. This study only looked at athletes of the adolescent age group. Future research should be done on college and professional athletes. Future researchers could also perform studies at the Division I, II, and/or III college level. Future subjects should also have some familiarity with the T-test. If subjects have consistently performed T-tests prior to data collection, it is less likely they will experience the “Learning Effect” as their bodies will have already adapted to the demands imposed by this agility test.

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APPENDIX A

REVIEW OF THE LITERATURE

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This review of the literature will discuss the effects of different stretching protocols on different measures of performance. A focus will be put on the effects proprioceptive neuromuscular facilitation (PNF) on those different measures of performance. A great deal of research has been done measuring various stretching protocols effect on strength, speed, peak torque, muscle activation, and other areas. Very little research has been done on these stretching protocols effects on agility and even less has been done with PNF. PNF is an alternative to traditional static and dynamic stretching protocols because of its various techniques and its effect on muscle spindles and the golgi tendon organs. The review of the literature will be divided into seven sections: Anatomy and Physiology, Principles/Techniques of PNF, Stretching and Flexibility/ROM, Stretching and Injury Risk Stretching and Strength/Power, Stretching and Speed, and Stretching and Agility. A summary of this information will also be included.

Anatomy and Physiology

First, to understand how stretching can be beneficial to different levels of performance and reduce injury risk, a review of the anatomy of physiology of muscles is necessary. Stretching causes several physiological changes in the muscles. To understand how stretching can be beneficial to performance and prevent injury, an understanding of these changes is necessary.

A microscopic look must be taken to discover the details of this process. Muscular organelles called Golgi Tendon Organs (GTOs) and muscle spindles are the target of stretching techniques, specifically PNF. GTOs are activated by tension in a muscle. If too much tension is placed on a muscle, the GTOs will send a signal directly to the brain and stimulate relaxation preventing the muscle from being overworked possibly causing injury [1-3].

Muscle spindles perform the opposite function. They respond to a muscle being overly stretched and will stimulate a contraction in response. PNF stretching is thought to target these structures specifically; inhibiting muscle spindles and increasing GTO activity allowing a muscle to stretch farther. This process is called autogenic inhibition which will be discussed later in this section. Autogenic inhibition may not be correct however as several researchers have found evidence that supports alternate theories. It is also proposed that signals from GTOs may reach the cerebral cortex in the brain and autogenic inhibition may be incorrect [1].

There is also evidence that autogenic inhibition may have decreased effects in regards to force production in muscle. This evidence states that relaxation of a muscle with stretching may be due to inhibition of muscle spindle only rather than the activation of GTOs as originally thought. It is the actions on these organelles that lead to increased flexibility and ROM [2-3].

The GTOs and Muscle Spindles interact with neurons to allow stretching to passively lengthen a muscle. This process is known as the Stretch Reflex and is the basis for every stretching technique. Muscle Spindles are proprioceptors that connect directly to the Central Nervous System (CNS). Muscle spindles contain two types of sensory nerve endings which innervate its fibers called intrafusal fibers. Skeletal muscle fibers are called extrafusal fibers. One type responds to dynamic changes in muscle length while the others continuously feed the CNS information about static muscle length. The latter will synapse in the anterior horn of the spinal cord. If the muscle is stretched, the sensory neurons in the spindle and the surrounding extrafusal muscles will also be stimulated causing contraction. This will lead to increased muscle tone. This increased muscle tone will provide resistance to overstretching. In addition to the increased muscle tone, if a muscle is stretched, Ia nerve fibers will relay the stimulation to the spinal cord. The Ia fibers synapse with Alpha motor neurons in the spinal cord which travel back to the muscle and cause a reflexive muscle action to relieve the stretch [4-5].

Muscle spindles are also simulated when they are compressed such as when a muscle is being shortened. When compressed, a muscle spindle will decrease muscle tone and reduce resistance to the movement being performed. Martini [6] gives the following example that illustrates this function. “If your elbow is flexed and you let gravity extend it, the triceps brachii muscle, which is compressed by this movement, relaxes.”

Muscle spindles are innervated gamma motor neurons which control the sensitivity of the spindle. The axons of the neurons are called gamma efferents. They decrease the sensitivity of the spindles whenever a voluntary muscle contraction takes place. Without this regulation, whenever a muscle is contracted, the muscle spindle would be compressed decreasing the muscle tone, hindering the contraction. The gamma efferents stimulate myofibrils in the intrafusal fibers causing it to stay at its normal resting length. This prevents compression from occurring during voluntary contraction and allowing the movement to take place and also keeping the spindle sensitive to other changes in muscle length [6].

The process by which GTOs are activated is very similar to muscle. GTOs are innervated by Ib neurons which can become compressed when a muscle is activated eliciting a sensory nerve signal to the CNS. The Ib nerve enters the dorsal horn where it will synapse with interneurons and then alpha motor neurons. These processes in regards to stretching will be elaborated on the section entitled PNF Principles/Techniques [1,6].

Golgi tendon organs and muscle spindles are the key components that make stretching beneficial. It is stretching’s influence on these organelles that allow a muscle to be more flexible. It is along with that increased flexibility that a person is able to also increase their Range of Motion (ROM).

Principles/Techniques of PNF

Proprioceptive Neuromuscular Facilitation stretches are a group of stretching techniques originally explored in the 1940s. The techniques were tested and collected by Voss et al. [7] They discussed the guiding principles of PNF. PNF stretching not only utilizes passive static stretching, but also tactile contact, vocal commands from the clinician, and muscular contractions. Tactile stimulation is used to facilitate contraction of target muscles. If tactile pressure is applied to an agonist muscle, the muscle's antagonist will be inhibited. This will allow the agonist to contract more efficiently and with more strength.

Vocal commands are a key component to successful PNF stretching. They signal the beginning of muscular contraction and should describe the desired muscular contraction as well as let the athlete know when to relax. Simple commands should be used such as "Push" or "Pull" to signal an isotonic contraction, "Hold" to signal an isometric contraction, or "Relax" to tell the athlete to relax their contractions [7].

Two other concepts important to PNF are Timing and Maximal Resistance. Maximal Resistance is the amount of force an athlete exerts against the resistance provided by the clinician. To achieve the maximum amount of facilitation, an athlete must provide the maximum resistance against the clinician.

Timing is also an important concept discussed. Timing is the sequence is which muscles contract. Naturally, our muscles develop movements moving proximal to distal. The same is true into our adult lives and is evident in PNF. Initially, rotational movements will be initiated in the extremities followed by other movements such as flexion/extension and abduction/adduction. Depending on the goal of the treatment, one of these movements will be needed to be inhibited by the clinician to focus on other movements [7].

Prentice [8] identified three PNF stretching techniques: Contract-relax, Hold-relax, and Slow-reversal-hold-relax. Prentice also identified a stretching protocol of a ten second static stretch followed by four second contraction would be effective. All three can be used to increase range of motion, muscle relaxation, and encourage inhibition.

Contract-relax involves first moving the target muscle passively into a stretched position. The subject is asked to contract the agonist (the muscle that will be stretched) concentrically against the resistance of the clinician.

This technique is useful when range of motion is limited by muscle tightness [8].

Hold-relax is the second PNF technique identified. This technique is very similar to contract-relax. The procedure is the same as contract-relax except when the contraction occurs, it is isometric. This technique can be used with either the agonist or antagonist muscle. It is useful when there is muscle tension on one side of a joint [8-9].

The final PNF stretching technique is called Slow-reversal-hold-relax. After the initial stretch of the antagonist, a concentric contraction of the agonist occurs followed by an isometric contraction of the antagonist. Like contract-relax, this technique is effective when the antagonist muscles are tight, limiting ROM at the given joint [8].

As stated in the previous section, GTOs and muscle spindles are muscular organelles that are the target of PNF and all other stretching techniques. There are several theories that potentially explain the mechanism for how these organelles are inhibited. These theories include Autogenic Inhibition, Reciprocal Inhibition, and Passive Properties of the Musculotendinous Unit (MTU) [2,3,6,10].

Autogenic Inhibition is a process that results from decreased GTO activity. Most stretching techniques take advantage of this but PNF is thought to lead to increased Autogenic Inhibition. The process begins because of increased tension placed on a muscle via a stretch. Muscular contraction of the agonist places even more tension on the muscle leading to an increased Autogenic Inhibition response. The stretch combined with the contraction will cause a high activation of GTO activity. The increased GTO activity will cause increased inhibition arising from the Ib interneurons, the neurons that connect in the dorsal horn to alpha motor neurons (Figure 1). This causes a reduced excitability in the target muscle, facilitating an additional stretch [6, 10].

Reciprocal Inhibition is a very similar process (Figure 2). Again, the target muscle will be stretched but the difference occurs when the opposing muscle is contracted. The activation of the motor neurons that contract the agonist will also stimulate Ia interneurons. These interneurons will inhibit the alpha motor neurons of the muscle being stretched. The deactivation of these motor neurons will allow for greater stretches [6, 10].

Finally, PNF is thought to be effective because of reasons related to the Passive Properties of the MTU. A muscle and its tendon have both viscous and elastic characteristics. The viscous components will elongate in response to a slow, sustained force but resist a rapid force. With a sustained stretch, the muscle will gradually allow itself to be lengthened. This property is commonly referred to as creep [10].

Stretching and Flexibility/ROM

The effect of stretching on ROM and Flexibility is a very common topic of research. Several relevant studies have been published in the last ten years on the topic. Most of these studies were done to determine the best possible protocols for increasing ROM at a given joint.

In 2006 Swanson examined the effects of different stretching protocols on ROM measurements. He explored static stretching techniques, stretching the muscle in a set position and holding the stretch for a specific time, vs. dynamic, functional stretching, stretching the muscle using specific types of continuous movement. The author concluded that the functional, dynamic exercises were more effective in increasing ROM [11].

Static and active stretching techniques and their effects were also studied in regards to hip extension ROM.

Researchers placed their subjects on a six week program and measured results at the program's completion. Results showed that although a significant gain was made in both groups compared to pre-test measures, there were no significant differences between the groups [12].

Other researchers examined static stretching but also looked at different durations of stretching. Subjects in this study were stretched for either thirty or sixty seconds after which a sit and reach test was performed as well as testing the subjects' maximal voluntary contraction. No significant differences were noted between the measures at thirty and sixty seconds [13].

Nelson and Bandy took a slightly different approach and compared static stretching to eccentric exercises and their effect on ROM measurements. They compared knee extension measurements taken from the 90-90 position. Both interventions significantly increased the ROM measurements but no difference was noted between the interventions [14].

Stretching has also been explored on the muscles of the upper extremity. The researcher stretched the shoulders of baseball pitchers and measured their throwing velocity and range of motion. This study however, yielded no significant results [15].

Several studies have compared PNF stretching techniques to other techniques. In one such study, the researches looked at the maximal stretch force that could be applied to person with tight hamstrings. Both PNF and static stretching were used on the subjects. PNF lead to increased stretch that could be applied as compared to static stretching [16].

Davis et al compared PNF, static, and self-administered stretching. The researchers measured knee extension in the 90-90 position. All three protocols significantly increased knee ROM but only static stretching was found to be significantly greater than the other two [17].

PNF, static, and dynamic stretching techniques' have also been compared in regards to their affect on ROM, strength, and other measures. No significant results were found in these cases. The researchers concluded that additional research was needed to determine the exact effects of the different stretching techniques [18].

Wen also looked at static stretching vs. PNF and measured hamstring flexibility in addition to peak torque and power. The results showed no significant difference between the two groups in these measures [19].

PNF was also compared to static and active stretching techniques. The three techniques were administered to different subjects and knee extension ROM measurements were taken several times after to determine if the stretching effects lasted long after the stretch was administered. Although significant gains were made in ROM, none of the techniques were found to be more beneficial than the other [20].

Pollard compared PNF to static stretching of the spine to determine if either was more effective in increasing hip flexion ROM. Pollard found that static stretching of the spine was more effective than PNF. He hypothesized that stretching the spine could decrease the likelihood of injury by assisting in increasing lower extremity ROM [21].

Marek et al conducted a study that compared PNF and static stretching and their effect on several areas including flexibility of the hamstrings. Among other results, the authors found that both PNF and static stretching significantly increased active range of motion (AROM) and passive range of motion (PROM) [5].

PNF and its effects have also been studied on their own on many occasions. Sharman et al reviewed several articles concerning PNF. The researchers explored the theories as to why PNF is supposedly more beneficial than other techniques as well as determining the best possible protocol to maximize performance. This investigation hypothesized that the best possible protocol for PNF is a shortening contraction of the antagonist followed by a static contraction of the agonist, held for at least 3 seconds and at least 20% of maximal intensity [10].

A final study looked at PNF and its effect on athletes who had stiff ankles. ROM as well as other measures were taken. Results showed that PNF stretching would significantly increase ankle ROM as compared to a control group [23].

Stretching and Injury Prevention

Because of the potential benefit of increased ROM, stretching is also thought to reduce the risk of injury. Research has been done in this area to confirm if this is true. Carter et al studied the effects of stretching on injury risk in 2000. The researchers performed both PNF stretching and ballistic stretching on the hamstrings then measured the muscular activity with electrodes. Results showed decreased activity in the biceps femoris muscle. The authors hypothesized the decreased activity was due to desensitization of the muscle spindles which could lead to injury [24].

Others took a different approach, determining if stretching had an effect on the subjects' joint position sense. After being stretched, subjects were asked to re-create either 30 or 15 degrees of shoulder adduction from a starting position of 45 degrees. Results showed no significant differences between stretching groups and a control group. They concluded shoulder position sense is not influenced by stretching [25].

Weerapong et al's research also looked at how stretching can be used to prevent injury. In addition to strength and ROM, they also measured subjects' soreness. The static, dynamic, and PNF stretching groups all reported less soreness compared to a control group although none of the groups was significantly different than the others. This provides evidence that stretching can prevent injuries and soreness in the active population [18].

Stretching and Strength/Power

In addition to stretching's effect on ROM and injury, another commonly researched topic is stretching's effect on measures of strength. Several studies already mentioned also used strength as a dependent variable in their research. Reviewing literature in this area revealed a common theme. In nearly every case, stretching was a detriment to measures of strength performance or no significant changes were noted.

The effects of different stretching protocols on isometric, eccentric, and concentric muscular performance as well as vertical jump have been explored in the past. The different stretching protocols significantly decreased performance in all these areas. The authors concluded that a stretching protocol to avoid these problems has not been determined or simply stretching may be detrimental to strength performance [26].

Vertical jump is often used to measure power and has been used several times in different studies. Another study compared three stretching interventions: static stretching, ballistic stretching, and PNF. With PNF and static stretching, a significant decrease in jump performance was noted while no differences were noted with ballistic stretching. The study took jump measurements at 5, 15, 30, 45, and 60 minutes after stretching. With each intervention, jump performance had recovered 15 after stretching [27].

Stipcak used a slightly different measure of strength in her study. The author used throwing velocity in baseball and softball players to measure strength. Static stretching was performed on the subjects after which, their throwing velocity was measured. As noted earlier, no significant changes in throwing velocity were noted [15].

As stated earlier, Weerapong et al compared static, dynamic, and PNF stretching. In addition to measuring ROM, the researchers also measured strength. Their results showed no significant changes in their subjects' strength [18].

Rees et al also measured strength in their study on PNF performed on the ankle. Their results were the anomaly in the research found. A significant increase in the strength of the plantarflexors was noted [23].

Other studies reviewed performed a more in-depth test to determine strength; attaching electrodes to determine maximal voluntary contraction, peak torque, and various EMG measurements. The study done by Marek et al on PNF was one such study. In the study, the PNF interventions caused significant decreases in the subjects peak torque, mean power output, and EMG amplitude despite the previous mentioned increases in ROM [22].

Papadopolous et al also did measurements on maximum voluntary contraction and EMG measurements as well as time taken to achieve maximum voluntary contraction, and other measures. These were taken after a short jog and seven different stretches as a warm-up. EMG measurements were the only variable to show a significant change [28].

Other work that studied only maximum voluntary contraction and EMG measurements has been researched. The researchers measured these variables in both the quadriceps and hamstring muscles. Results showed a decrease in maximum voluntary contraction but an increase in EMG measurements. The authors concluded that the detriments seen post-stretching are due to inactivity rather than the increased elasticity [29].

Wen looked at only mean power output and peak torque of the hamstrings in his study comparing PNF to static stretching. Results showed no significant results between the two stretching groups. The author concluded that while stretching is beneficial, one technique is not more beneficial than the other [19].

Ogura et al also looked at just maximum voluntary contraction in addition to hamstring flexibility with thirty and sixty second bouts of stretching. As with ROM measurements, results showed no significant differences in the maximum voluntary contraction measures [13].

Stretching and Speed

Another common measure of athletic performance is an athlete’s speed. Curiously, the effects of stretching on sprint performance have received little research attention. One area that has received attention is the effects of several stretching protocols on fifty meter sprint times. Only one protocol showed a significant change. A static, passive stretch combined with an active, dynamic stretch produced significantly slower sprint times [30].

Nelson et al examined the effects of three different static stretches compared to no stretching in twenty yard sprint times of sixteen division one college track athletes. Once a week a different stretch was given and measure were taken. With each of the three stretches, results showed a significant increase in sprint times compared to no stretching revealing a decrease in performance [31].

Stretching’s effect on sprint performance has also been examined in rugby players. Four different warm-up protocols were included in this study: passive static stretch, active dynamic stretch, active static stretch, and static dynamic stretch. Results showed a significant increase in the sprint times of the passive static stretch and active static stretch groups. A significant decrease in sprint times of the active dynamic stretch group was also noted [32].

Stretching and Agility

A final area that has been explored that must be discussed is the effect of stretching on agility. This area has also received very little attention from researchers. Oakley explored static and dynamic stretching and its effect on T-test times, a measure of agility. Both stretching interventions showed significantly lower T-test times compared to control with the dynamic stretching group showing significantly lower times than the static stretching group [33].

Faigenbaum et al included agility measures in their studies on teenage athlete. The researchers measured shuttle run times along with vertical jump, medicine ball toss, and ten yard sprint; all measures of anaerobic performance. These measures were taken once after a static stretching warm-up and another time after a dynamic warm-up. A control trial was also measured. In regards to agility, no significant difference was noted in any of the groups [34].

Faigenbaum's other study with different colleagues focused on children. This study also examined different warm-up protocols' effect on several measures including agility. The protocols included five minutes of walking followed by five minutes of static stretching, ten minutes of dynamic exercise, or ten minutes of dynamic exercise plus three drop jumps from a fifteen centimeter box. Results revealed a significant decrease in agility measures with five minutes of walking and five minutes of static stretching compared to the ten minutes of exercise with three drop jumps measures [35].

McMillian et al. also examined static vs dynamic stretching warm-ups on agility. This study was done on thirty military cadets. The two protocols each lasted thirty minutes and the subjects were asked to perform T-tests for agility. In this case, no significant differences were present between the two groups [36].

Stretching seems to have many diverse effects on different measures of performance. Stretching affects the Golgi tendon organs and muscle spindles, two microscopic organelles inside muscles that respond to excess tension or stretch. Stretching seems to have a beneficial effect on ROM and injury prevention but a detriment to strengthening.

Research into other areas is lacking or has been inconclusive specifically in the area of agility.

APPENDIX B

THE PROBLEM

Statement of the Problem

Research into the area of Stretching's effect on agility is lacking. The little research that is available shows that stretching may improve an athlete's performance in agility tests. One stretching technique that has not been explored in regards to agility is proprioceptive neuromuscular facilitation (PNF). Also, the different styles of PNF have not been compared in measures of performance in any study found. Therefore this study was performed to determine if PNF stretching is beneficial to agility and if two PNF techniques had a significant difference between them in the same agility tests.

Definition of Terms

The definition of the following terms was used in this study.

1. PNF Stretching – several stretching techniques that involve a passive, static stretch followed by a contraction of the agonist and/or antagonist muscle and finally another passive, static stretch [7].
2. Hold-Relax Stretching – A technique of PNF stretching involving a 10 second passive, static stretch of the

target muscle followed by a 4 second isometric contraction of the agonist [8].

3. Contract-Relax Stretching – A technique of PNF stretching involving a 10 second passive, static stretch of the target muscle followed by a 4 second concentric contraction of the agonist [8].
4. High School Athlete – subject who is a participant in at least one of the sports Burgettstown High School competes in.
5. Physically Active Subject – one who participates in at least 30 minutes of exercise (cardio, resistance training, etc.) for at least 3 days a week [37].
6. Isometric – action in which a muscle develops tension, but does not shorten; also called a static contraction. No movement occurs [38].
7. Concentric – occurs when a muscle is activated and shortens [38].
8. Eccentric – occurs when a muscle is activated and force is produced but the muscle lengthens [38].
9. Agility – The ability to control the direction of a body or its parts during rapid movement [39]. In regards to this study, a person’s agility will be measured by their performance in the T-Test.

10. Range of Motion (ROM) – Amount of movement within a joint. Range of motion is affected by soft-tissue mobility and can be influenced by strength when performed actively [39].
11. Flexibility –Mobility of a body segment, dependent on soft-tissue tolerance and the ability of soft tissue to move with forces applied to it. Flexibility can involve soft-tissue mobility alone or in combination with joint motion [39].

Basic Assumptions

The following assumptions were made when conducting the research:

1. The PNF techniques Contract-Relax and Hold-Relax are performed correctly.
2. The T-test for agility was set-up correctly and the times collected from the subjects' tests are accurate.
3. The subjects will perform no other flexibility exercises when participating in this study.
4. The "T" agility test is valid and reliable.
5. The Speed Trap II Timer is a valid and reliable timing device.
6.

Limitations of Study

The following limitations were noted in this study:

1. Subjects were gathered only from volunteers from Burgettstown High School.
2. Every PNF stretching technique was not utilized. Only the techniques Contract-Relax and Hold-Relax were utilized.
3. Agility was the only measure of performance tested in this study.

Significance of Study

Stretching has traditionally been part of an athlete's warm-up procedures. Most research into stretching has dealt with how it affects an athlete's Range of Motion. Other studies have examined stretching's effect on strength and power, injury risk, speed, and agility. However, the effects on agility have not been researched extensively. Although research is minimal, the effects of stretching on agility have shown to be beneficial in some studies.

Proprioceptive neuromuscular facilitation is a stretching strategy composed of several different techniques, which have shown to be beneficial in several areas including Range of Motion. It has shown to allow for greater stretches compared to other techniques thereby allowing for greater improvements in an athlete's Range of Motion. However, PNF's effects on performance have not been researched extensively. Also, the several types of PNF stretching have not been compared in any capacity the researcher could find. This study will compare trials of two of these techniques in an agility test along with a control trial.

By performing this study, the researcher hoped to uncover another, better stretching technique that may improve an athlete's performance. The researcher also hoped to discover if the benefits offered by the techniques of PNF are significantly different from one another. PNF encompasses several stretching techniques which not only stretch the muscles but also expose the muscles to contractions. There may be a more beneficial combination of stretching and muscular contraction compared to others. The results of this study may change warm-up procedures in sports where agility is an important component. PNF stretching may become a favorite procedure of coaches and personal trainers everywhere. The researcher hoped that the study would not only identify new, effective warm-up procedures, but generate questions for further study into stretching techniques and warm-up protocols.

APPENDIX C

ADDITIONAL METHODS

APPENDIX C1

Informed Consent Form

Informed Consent Form

The Effect of PNF Stretching on the Agility of High School Athletes

California University of Pennsylvania
California, Pennsylvania 15419

Responsible Investigator: Brett Piper ATC

I/ My child has been asked to participate in a research study that investigates the effects of two separate stretching techniques on agility as measured by the T-Test. In participation of this study, I/ my child agrees to: perform three (3) agility tests under the supervision of Brett Piper ATC, each test will be performed after receiving one of two stretching protocols plus a control trial where no stretching will be performed. I/ My child will not perform any additional stretching exercises, resistance exercise, or cardiovascular exercise during his/her participation in this study. I/He/she will not share any information related to the results of this study I/he/she may be made aware of during my participation. My/His/Her participation in this study may lead to findings which show that the selected stretching protocols are beneficial to an athlete's agility as well as any possible differences between the two different protocols.

I understand that:

A. The possible risks of this procedure include possible injuries as a result of performing the T-Test for agility such as fatigue, muscular strain, ligament sprain, possible asthmatic episode if applicable, or injuries related to the impact from falling such as contusions, fractures, or concussion. All stretching will be performed by the researcher who will also closely monitor all testing procedures. The possible benefit to me of this study is knowing if the selected stretching techniques are beneficial to agility as well as knowing if differences are present between the techniques.
B. Any questions I have concerning my participation in this study will be answered by Brett Piper ATC (419-366-0088).
C. I understand that I may refuse to participate from this study at any time without any negative consequences. Also, the investigator may stop at any time. I also understand that no information which identifies me/my child will be released without my separate consent and that all identifiable information will be protected to the limits allowed by law. If the study design or the use of the data is to be changed, I will be so informed and my consent re-obtained. I understand that if I have any questions, comments, or concerns about the study or the informed consent process, I may write or call Department of Health Sciences and Sports Studies, California University of Pennsylvania, 250 University Ave., California, PA 15419. Phone: 724-938-4000.
D. I have received a copy of this consent form and the Research Participants' Bill of Rights.

I have read the above and understand it and hereby consent to the procedure(s) set forth.

SUBJECT____
PARENT/GUARDIAN (if Necessary) ______________________________________
DATE_______________

INVESTIGATOR_____________________________________

APPENDIX C2

Permission from Burgettstown High School

California University of Pennsylvania
250 University Avenue
California, PA 15419-1394
www.cup.edu

DEPARTMENT OF HEALTH SCIENCE AND SPORT STUDIES

Building Character. Building Careers.

724-938-4562 | 724-938-4342 FAX

I, JON VALLINA hereby grant permission for Brett Piper ATC to perform his thesis, *The Effects of PNF Stretching on the Agility of High School Athletes*, using the facilities and students of Burgettstown High School during the months of February through April of 2009.

Jon Valli

Signature

2/2/09

Date

California University of Pennsylvania
250 University Avenue
California, PA 15419-1394
www.cup.edu

DEPARTMENT OF HEALTH SCIENCE AND SPORT STUDIES

Building Character. Building Careers.

724-938-4562 | 724-938-4342 FAX

I, Chris Wolfson hereby grant permission for Brett Piper ATC to perform his thesis, *The Effects of PNF Stretching on the Agility of High School Athletes*, using the facilities and students of Burgettstown High School during the months of February through April of 2009.

[signature] ________________ Signature

2/2/09 ________________ Date

APPENDIX C3

Institutional Review Board -

California University of Pennsylvania

California University
of Pennsylvania

Proposal Number
08-039
Date Received
____

PROTOCOL for Research Involving Human Subjects

REVISED

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 : The Effects of PNF Stretching on the Agility of High School Athletes

Researcher/Project Director: Brett Piper

Phone # 419-366-0088 ***E-mail Address*** PIP1887@cup.edu

Faculty Sponsor (if required) Dr. Robert Kane

Department Health Sciences and Sports Studies

Project Dates January 2009 ***to*** May 2009

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://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 __________

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(ses)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 will be to examine the effects of stretching, specifically PNF stretching on the T-Test for agility. The researcher will receive approval from the Institutional Review Board Approval (Appendix) at California University of Pennsylvania before conducting any research. Subjects for this study will be male and female athletes attending Burgettstown High School in Burgettstown, Pennsylvania. As there is the potential that all or most of the subjects could be minors, consent will be given from the parents/guardian if applicable as well as assent from the subjects. Subjects will be informed of all risks prior to their participation and will be given the option to drop out at any time. Permission from Burgettstown's athletic director and principal will also be obtained. Subjects will perform three trials of the T-Test; a valid and reliable test for assessing a subject's agility. The T-Test is performed using 4 cones placed in a "T" formation. One cone (Cone A) is placed to form the base of the "T" while the other 3 (Cones B, C, and D) form a straight line in front of Cone A. Cone B is located 10 yards directly in front of Cone A. Cones C and D are placed 5 yards to the left and right of Cone B. Subjects performing the test use Cone A as a starting and finishing point. Subjects sprint from Cone A to Cone B, bend down and touch Cone B with their hand. From Cone B, subjects shuffle to Cone C and touch it. From Cone C, subjects shuffle to Cone D and touch it with their hand. Subjects then shuffle from Cone D back to Cone B and perform a final touch of Cone B. After this final touch, subjects backpedal to Cone A to complete the test. One trial will be performed after a bout of "Hold-Relax" PNF stretching. Another trial will be performed after a bout of "Contract-Relax" PNF stretching. A final trial will be performed with no stretching and will serve as a control trial. Trials will be performed one at a time over at least 3 days. The order of these trials will be randomized for each subject. Stretching will be performed on the quadriceps and hamstring muscles of each subject. "Hold-Relax" stretching will consist of the researcher stretching the target muscle for ten seconds followed by the subject isometrically contracting the agonist for ten seconds against the researcher's resistance. "Contract-Relax" stretching will consist of the researcher stretching the target muscle for ten seconds followed by the subject concentrically contracting the agonist for ten seconds against the researcher's resistance. The hamstring stretches will be performed with the subject in the supine position. The target muscle will be placed in full knee extension and passively moved into hip flexion. The opposite leg will be kept flat on the ground. During contractions, the subject will be asked to actively perform additional hip flexion. For the quadriceps stretches, subjects will be placed in the prone position. Subjects will be moved passively into both knee flexion and hip extension with the opposite leg flat on the ground. During contractions the subject will be asked to actively perform additional knee flexion and hip extension. Once the stretching is completed, the subject will complete a T-test to measure for agility. Times will be measured using a Speed Trap II Timer. The risks associated with these procedures are minimal and are no greater than participation in sports. With any stretching exercise, the possibility exists that the subject could be stretched farther than their tolerable limit creating musculoskeletal injuries. Also, because the T-Test involves the subject sprinting, shuffling, and backpedaling, the subject could also be injured performing the test. Ligament sprains, muscle strains, and impact injuries resulting from a fall could also occur. These impact injuries include contusions and/or concussions. Subjects with exercise-induced asthma may also be at risk despite the brevity of testing procedures. However, these dangers are minimal and are no greater than participation in sports. No statistics related to the incidence of injury performing a T-Test could be found by the researcher.

The following hypotheses will be tested in this study:

1. Trials performed after "Hold-Relax" stretching will show significantly lower agility test times compared to a control trial.
2. Trials performed after "Contract-Relax" stretching will show significantly lower agility test times compared to a control trial.
3. Trials performed after "Contract-Relax" stretching will show significantly lower agility test times compared to "Hold-Relax" trials.
4. Male trials of "Contract-Relax" will be significantly different than female "Contract-Relax" trials.

5. Male trials of "Hold-Relax" will be significantly different than female "Hold-Relax" trials.

An alpha level of .05 will be used to determine a level of significance. Statistical Package for Social Sciences (Version 16.0, SPSS, Inc., Chicago, IL) will be used for the statistical analysis of this study. A factorial MANOVA will be used to determine if any differences between the stretching trials and the control trials as well as any gender differences.

Prior to conducting research on the Burgettstown students, a pilot study will be done on 3-4 California University of Pennsylvania graduate students. This will be done to familiarize the researcher with the testing procedures and equipment. The same testing procedures will be used in the pilot as described above. Informed consent will be obtained from the subjects used in the pilot. Their identities and test results will also be kept confidential.

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.*

Because this study involves participants being stretched and actively performing an agility test, a few albeit minor risks are involved. As with any stretching protocol, the possibility exists that a subject could be stretched beyond their tolerable limit creating muscular injury. The researcher will be performing all stretches and will follow a predetermined protocol and is skilled in these techniques. The researcher will also carefully monitor the subjects during stretching and ensure the stretching will stay within tolerable limits. Also as subjects will be performing an agility test that requires sprinting, quickly changing directions, and accelerating the possibility of other physical injury exists in the form of muscle strains, ligaments sprains, or impact injuries from falling such as contusions or concussion. However, these risks are no greater than that of sports participation. To minimize this possibility, all agility trials will be performed on the same stable, level surface. Participants will also not be allowed to complete a trial unless they are wearing the proper clothing and footwear. The researcher will also be present not only to measure time, but also to provide any first-aid that may be required. The researcher is a certified Athletic Trainer and is qualified to provide treatment for any injuries that may occur. The researcher will also closely monitor all subjects during testing procedures and will respond accordingly in the event of injury. Subjects will also be given the option to discontinue participation at any time. If a subject is injured at any time during testing, he/she will be disqualified from the study and their results will not be used.

   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.*

As the study will focus on the effects of PNF on athletes, only subjects who participate in at least 1 sport at Burgettstown High School will be accepted. Also, only athletes not participating in a sport during testing procedures will be accepted. Testing procedures may interfere with these athletes' schedule as well as the increased possibility of injury or fatigue present when being tested. Athletes will also be tested as it is more likely that athletes will perform better in the T-Test and have less chance of injury compared to un-trained, inactive persons. Subjects will not be coerced by teachers or coaches to participate in this study.

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.*

As the researcher is in close contact with the athletic population at Burgettstown, the researcher will discuss the possibility of participating in this study with the Burgettstown coaches, athletic director, and athletes themselves. The researcher will ask athletes to volunteer for participation in this study.

As subjects may mostly be minors, two forms will be used to obtain consent. Informed assent forms will be given to participants who are minors as well as informed consent forms to be completed by parents of minors or subjects who are of age. Documented permission will also be obtained from the Burgettstown High School Athletic Director.

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.*

Confidentiality will be guaranteed in the informed consent form. Until data is entered into a computer, data collection sheets will be created by the researcher. When not collecting data, all data collection sheets will be kept in a locked filing cabinet kept in the researcher's office at Burgettstown High School. The key will be kept with the researcher. Upon completion of the project, all data collection sheets will be kept with the researcher and kept in a locked desk. Again, the key to the desk will be kept with the researcher. Collection sheets will be kept by the researcher for five years.

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

☒ *Adult volunteers*	☐ *Mentally Disabled People*
☒ *CAL University Students*	☐ *Economically Disadvantaged People*
☒ *Other Students*	☐ *Educationally Disadvantaged People*
☐ *Prisoners*	☐ *Fetuses or fetal material*
☐ *Pregnant Women*	☒ *Children Under 18*
☐ *Physically Handicapped People*	☐ *Neonates*

4. *Is remuneration involved in your project?* ☐ *Yes or* ☒ *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.

Draft, April 7, 2005

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 to 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

Brent Pryer

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.

as amended

☒ Approved ☐ Disapproved

Chairperson, Institutional Review Board | Date 02-13-09

Draft, April 7, 2005

APPENDIX C4

Demographic Information Sheet

Demographic Information Sheet

Name:___________________________
Subject #:________

Age:___________________ Gender: M / F

Height:________________ Weight:___________

In the last 3 months have you sustained any lower extremity (hips, thighs, knees, shins, feet, toes) injury that caused you to seek medical attention?

Yes / No

Do you exercise at least 3 days a week for at least 30 minutes?

Yes / No

Please list your primary sport at Burgettstown. (The sport you spend the most time in practice/preparation both in-season and offseason.)

APPENDIX C5

Individual Data Collection Sheet

Data Collection Sheet

Subject #:________ Subject Initials:______________

Intervention/Order	Time
Control Order:	
Hold-Relax Order:	
Contract-Relax Order:	

APPENDIX C6

Stretching Positions

Hamstring Stretch

Quadriceps Stretch

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ABSTRACT

Title: THE EFFECTS OF PNF STRETCHING ON THE AGILITY OF HIGH SCHOOL ATHLETES

Researcher: Brett Piper, ATC, PES

Advisor: Dr. Robert Kane, PT, ATC

Date: May 2009

Research Type: Master's Thesis

Context: Past research has shown that stretching prior to participation may have a positive effect on the agility of athletes. PNF stretching techniques have been found to be beneficial to several areas of performance. However, PNF stretching techniques have not been explored in this area nor has research compared two or more PNF techniques to each other.

Objective: The purpose of this study was to determine if PNF stretching techniques had a significant effect on the agility test times of high school athletes.

Design: Repeated Measures, Within Subjects design.

Setting: Controlled laboratory setting.

Participants: Fifteen male and fifteen female physically active high school students (age = 15.8 ± 1.4 yrs. Weight = 157.5 ± 35.5 lbs.) from Burgettstown High School in Burgettstown, Pennsylvania who also participate in athletics.

Interventions: Each subject was tested on three separate days under three different stretching interventions (No stretching, Hold-relax PNF, and Contract-relax PNF). Stretching was performed on the hamstrings and quadriceps muscles. Each muscle group was stretched three times under each condition with a ten second static stretch period followed by a four second contraction of the muscles' antagonist. After stretching was completed, each subject performed a T-Test for agility.

Main Outcome Measures: Mean times were calculated from all three trials of all thirty subjects and compared using a Repeated Measures Analysis of Variance (ANOVA) with an alpha level of $< .05$.

Results: No significant differences were found between the control trials and the two PNF stretching techniques ($F_{2,56} = .046$ $p > .05$). Mean times of the control trials were found to be 11.63 ± 1.41. The mean times of the Hold-relax and Contract-relax trials were found to be 11.59 ± 1.31 and 11.64 ± 1.36 respectively. However, additional findings found that no matter the condition, the male subjects exhibited significantly lower times compared to the female subjects.

Conclusions: This study revealed that a PNF protocol of a ten second static stretch followed by a four second contraction is not sufficient to gain significant improvements in performance in regards to agility. Previous studies using a thirty second static stretch and a five second contraction have shown significant differences in other areas of performance. Additional testing using similar protocols with a thirty second stretch and a five second contraction should be done to determine if PNF stretching can be beneficial to agility as other techniques have shown to be.

Word Count: 395