

THE EFFECTS OF STATIC AND DYNAMIC STRETCHING ON BALANCE
MEASURES DURING THE PERFORMANCE OF A GOLF SWING

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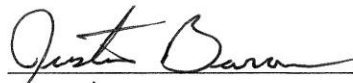
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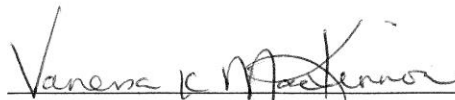
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INTRODUCTION

Performance enhancement is very popular today and there is a growing market in the athletic industry for performance enhancement programs and equipment. Any serious athlete is always looking for that extra edge in sports performance whether it is experimenting with supplements or using new training techniques. Warm-ups prior to athletic performance are commonly performed by recreational and professional athletes alike as a method to enhance performance and prevent injury. Stretching is commonly used by athletic trainers and sports medicine professionals for injury prevention and sports performance enhancement.¹

Golf is no different from other sports in that stretching routines are commonly performed prior to swinging the golf club. There are multiple types of stretching but the two stretching techniques that are most commonly seen during a warm-up prior to an exercise bout are static and dynamic stretching.^{2-6,7-14,15-20,21}

The effects of static stretching have been researched relating to many different areas of physical performance

including flexibility, muscular speed, and muscular power to name a few. It is well known in the research that static stretching will increase flexibility, short and long-term depending on the regimen,^{12,22,23} but also has the potential to have detrimental effects on performance.²⁻

^{4,6,8,13,14,16,17,22,23} A review of literature by Janot, Dalleck, and Reymont¹⁴ compared static stretching with other stretching techniques and found that in all of the performance measures tested, vertical jump, drop jump, peak force, and maximal voluntary contraction of the quadriceps and plantar flexor muscles, were either unchanged or decreased.¹⁴

Dynamic stretching has been gaining popularity in sports due to its positive effects. Research has found time and time again that not only will it increase flexibility,¹² but unlike static stretching, it has the potential to actually increase performance.^{2,3,5,7,9-12,14-19} No articles were found in the course of this review that showed a decrease in performance following dynamic stretching.

Clearly, the type of stretching a golfer chooses before playing may impact their swing significantly. Balance is an important performance aspect, especially in the sport of golf.³³ Highly skilled golfers tend to have

better balance than lower skilled golfers.²⁴ There has been very little research that has examined how balance is affected by stretching, and the potential effects that stretching could have on balance during the golf swing may be the difference between winning and losing a tournament.

There is no single golf-specific warm-up that has been used by all golfers. The warm-up routine is usually based on the golfer's previous experience and what they prefer to do to help them prepare for a round. The purpose of this study is to examine the effects of static and dynamic stretching routines on balance during the golf swing. This will provide athletic trainers, performance enhancement specialists, and clinicians alike a more specific and intelligent way to guide golfers towards a proper warm-up. With a more specific warm-up regimen, golfers can improve their performance, or at the very least prevent them from inadvertently hurting their own performance.

METHODS

The primary goal of this study was to examine the effect of different stretching interventions on balance during the performance of a golf swing. Static stretching versus dynamic stretching of the lower extremity was compared to determine their effects on balance and stability of the athlete during the golf swing performance. The following section includes these subsections: research design, subjects, instruments, procedures, hypotheses, and data analysis.

Research Design

This research was a quasi-experimental, within subjects, repeated measures design. The independent variable was stretching condition. There were two levels: static and dynamic stretching conditions of the lower body. The dependent variable was balance during a golf swing as measured by the Science and Motion BalanceLab®.

Subjects

The subjects that were tested in this study included 19 volunteer male golfers over the age of 18, from the Professional Golf Management program and the golf team at California University of Pennsylvania. All subjects had to be healthy and not currently suffering from an injury to the upper or lower body that would affect their performance in this study or place them at greater risk for injury due to their participation.

Each subject was required to participate in two testing sessions, one measuring the dependent variables following a static stretching protocol, and one measuring the dependent variables following a dynamic stretching protocol. All subjects in the study signed an Informed Consent Form (Appendix C1) prior to participation in the study. The study was approved by the Institutional Review Board at California University of PA prior to any data collection. Each participant's identity remained confidential and was not to be included in the study.

Preliminary Research

There was a pilot study conducted with this research project. Three healthy and proficient golfers were used to test this protocol. The subject performed all of the testing procedures. The researcher looked for the subject's ability to understand directions, the amount of time used to complete the tasks and if the warm-up protocol before service testing is accurate. Data was collected on the data collection sheet (Appendix C2).

Instruments

The main instrument that was used was the Science and Motion BalanceLab force plate. It is a high resolution force plate that can evaluate balance and weight transfer during a golf swing. All participants used a driver for their tests as suggested by the golf professional. Each subject used a driver of their choice to ensure the subject is as comfortable as possible to not place any uncontrolled effect on the dependent variable. The Science and Motion BalanceLab® software was used on a computer in the golf performance lab at California University of Pennsylvania.

Procedures

Each participant performed a static stretching routine (Appendix C) on day one, and a dynamic stretching (Appendix C) routine on day two. There was three static stretches and three dynamic stretches each lasting a duration of 30 seconds with a minute rest in between repetitions. This duration was chosen based off previous research.³⁴ The static stretches that were used were the standing calf stretch, sitting single-leg hamstring stretch, and a prone quadriceps stretch. The dynamic stretches that were used were the calf step-backs, standing leg swings for hamstrings, and standing butt-kicks for the quadriceps.

Immediately following the stretching, the subject then stood on the balance platform and performed 10 golf club swings with 1 minute of rest in between each swing.^{16,17} Confidence ellipse width: the forward and backward sway of the subject on the balance plate; and confidence ellipse angle: the degree the subjects stance on the balance plate was relative to the target the balls were hit at (a perpendicular stance being 90°), were measured by the balance force plate to determine if static or dynamic stretching had positive or negative effects on overall balance during the performance of a golf swing. Other

balance measures such as confidence ellipse height and center of force measures defined in the appendix were also recorded and will potentially be explored as part of this project.

Hypotheses

The following hypotheses were formed based on previous research and by the researcher's conclusions from a review of the literature.

- 1) There will be an improvement in balance as measured by the confidence ellipse width in the dynamic stretching group when compared to the static stretching group.
- 2) There will be an effect on the confidence ellipse angle in the dynamic group as compared to the static stretching group.

Data Analysis

All data was analyzed by SPSS version 19.0 for windows at an alpha level of 0.05. The research hypotheses were analyzed using a repeated measures multivariate analysis of variance (MANOVA).

RESULTS

The purpose of this study was to examine the difference between two different stretching protocols (static stretching and dynamic stretching) on balance measures during the performance of a golf swing. The following section contains the data that was collected during this study.

Demographic Information

Twenty male subjects in the Professional Golf Management Program, on the Division II golf team, or both at California University of Pennsylvania volunteered for this study. Nineteen subjects completed all the testing and one dropped out due to injury unrelated to the study. All subjects that completed the testing were considered healthy and did not suffer from any type of injury or illness during the testing period. These individuals were all skilled golfers; while specific handicaps were not a factor for this study, all of the subjects had a handicap lower than 15.

Hypothesis Testing

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

Hypothesis 1: There will be an improvement in balance as measured by the confidence ellipse width in the dynamic stretching group when compared to the static stretching group.

Hypothesis 2: There will be an effect on the confidence ellipse angle in the dynamic stretching group as compared to the static stretching group.

A repeated measures analysis of variance (ANOVA) was performed comparing the effects of the independent variables, static stretching and dynamic stretching, on the dependent variables, confidence ellipse width and confidence ellipse angle. On the first hypothesis, no significant difference was found ($F(1,18)=1.32, p > .265$). The test revealed no significant difference between the static ($54.85\text{mm} \pm 21.99$) and dynamic ($52.48\text{mm} \pm 16.60$) stretching conditions on confidence ellipse width. In the second hypothesis, a significant difference was found ($F(1,18)=5.03, p > .038$). The test revealed there was a

significant difference between the static ($83.35\text{deg} \pm 4.26$) and dynamic ($82.74\text{deg} \pm 4.31$) stretching conditions on the confidence ellipse angle.

Additional Findings

In addition to testing the above hypotheses, the researcher also measured the effects of the independent variables on confidence ellipse height since the SAM BalanceLab automatically recorded the data alongside the rest of the data. On the additional test no significant difference was found ($F(1,18)=3.97$, $p > .062$). The test revealed no significant difference between the static ($288.18\text{mm} \pm 66.10$) and dynamic ($299.01\text{mm} \pm 73.33$) stretching conditions.

Table 1. Balance measures dependent on stretch

Warm-up	Confidence ellipse width, mm	Confidence ellipse height, mm	Confidence ellipse angle, deg
Static	54.9 (21.99)	288.9 (66.10)	83.3 (4.26)
Dynamic	52.5 (16.60)	299.0 (73.33)	82.7 (4.31)

DISCUSSION

The following section is divided into three subsections: Discussion of results, conclusions, and recommendations for further research.

Discussion of Results

It is very common for athletes to perform warm-ups prior to activity regardless of skill level. Sports medicine professionals use stretching for injury prevention, rehabilitation, and sports performance enhancement.¹ The two stretching techniques that are most commonly seen prior to performance are static and dynamic stretching.²⁻²¹ Because these two stretching techniques are so common, many research studies have been performed on both stretches to find out their true effects.

Static stretching has been tested on several measures of performance including flexibility, muscular speed, and muscular power. It has been found time and time again that static stretching will increase flexibility both short and long-term depending on the stretching regimen.^{12,22,23} The

research has also found that static stretching can have detrimental effects on performance measures.²⁻

4,6,8,13,14,16,17,22,23

Dynamic stretching is growing in popularity, especially in the elite levels of sports because the research is showing positive effects. It has been found that dynamic stretching will increase flexibility¹² as well as in many cases increase performance measures.^{2,3,5,7,9-12,14-19} The purpose of this study was to examine the effects of static and dynamic stretching routines on three different balance measures during the golf swing.

It was hypothesized that the dynamic stretching condition would yield better results in terms of stability in the three measurements that were recorded by the Science & Motion BalanceLab: confidence ellipse width, confidence ellipse angle, and confidence ellipse height. Statistical analysis revealed no significant difference on the confidence ellipse width and height measures. There was a statistical significant difference between static and dynamic stretching conditions on the confidence ellipse angle.

The results of this study show mixed results among static and dynamic stretching effects. The insignificant results from the two tests contradict most of the research

on performance measures. In a review of literature by Cervantes and Snyder,¹⁰ dynamic warm-ups were compared to static and PNF stretching conditions in college athletes. The conclusions from this review of literature suggested that dynamic warm-ups would be more beneficial to performance than the other two stretching conditions.

Several studies examined the effects of static stretching on different performance measures finding little to no positive effects on such measures.^{5-9,11,15,20,21,25,26} The only measure that was positive was that static stretching significantly improved active and passive ranges of motion.^{5,6,19} Finally, a review of literature by Janot, Dalleck, and Reymont¹⁴ compared static stretching with dynamic, ballistic, and PNF stretching. Performance measures included vertical jump, drop jump, peak force, and maximal voluntary contraction of the quadriceps and plantar flexor muscles. In the static stretching condition, all of the performance measures were either unchanged or decreased, suggesting that there may be a better form of stretching prior to performance.

Finally, the last test found that the dynamic stretching condition had a statistically significant effect on confidence ellipse angle when compared to the static stretching condition. Although the data suggests that a

dynamic stretch may be more beneficial than a static stretch in this case, there is no evidence to discuss whether the confidence ellipse angle plays an important role during the golf swing. Based on the conclusions from this study, recommendations have been provided for further research in order to investigate the mixed results that were obtained.

It must be noted that the data was collected in a lab on a hard, flat force plate and the subjects were tested in tennis shoes. This may not translate well to the golf course because most golfers wear golf shoes which have extra grip and may actually improve their balance on a grassy surface compared to a lab. Also, some of the subjects noted that they wouldn't feel as comfortable performing the dynamic stretches that were used in this study in a live situation.

Conclusions

The results of this study discovered the following conclusions to aforementioned hypotheses:

1. There was no significant improvement in balance as measured by the confidence ellipse width in the

dynamic stretching group when compared to the static stretching group.

2. There was a significant effect on the confidence ellipse angle in the dynamic stretching group as compared to the static stretching group.
3. There was no significant effect in the additional findings on the confidence ellipse height in the dynamic stretching group as compared to the static stretching group.

The data collected in this study provide mixed results regarding stretching effects on balance. It cannot be concluded that one type of stretching is better than the other prior to performance in golf. It is this researcher's opinion that golfers should maintain a warm-up of their choosing that is comfortable for them until future research shows clearer results.

Recommendations

The following recommendations should be considered to expand upon this research:

1. Perform the same study using a female only population in order to determine if there are any possible gender differences.

2. Expand the research to determine the role of the confidence ellipse angle during the golf swing to find out if the significant results in this study are meaningful.
3. Expand the research to determine if a different type of dynamic warm-up such as a stationary bike warm-up is more effective than a static warm-up.
4. Conduct a study on the effects of a long-term stretching program.
5. Perform tests on the other measurements recorded by the SAM BalanceLab in this study that were not examined.
6. Expand the research on the additional finding confidence ellipse height because the p-value was .062, close to being significant.

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APPENDICES

APPENDIX A
Review of Literature

INTRODUCTION

For years, athletes of all different skill levels and sports have employed stretching as part of their warm-ups prior to exercise or events. Certain sports, such as golf, require a more sport-specific warm-up due to the nature of the game. Golfers at the recreational and competitive levels have begun including stretching routines in their pre-event warm-ups in hopes of increasing their performance. The purpose of this literature review is to determine the effects of different stretching interventions on balance during the golf swing to help provide golfers with the best possible warm-up before an event.

Biomechanics of Golf

Several different studies have been performed on the important aspects of movement kinematics from the human body during a golf swing. These aspects focus mainly on their effects on distance once the ball has been struck by the golf club. The most relevant motions that affect the typical golf swing are upper torso-pelvic separation (X-

factor), rapidly stretching the hip, trunk, and upper limb upon backswing, trunk lateral bending, and superior pelvic weight shift.¹⁻⁴

All articles examined in this review on the biomechanics of the golf swing determined that upper torso-pelvic separation (X-factor) was a critical factor in golf swing performance.¹⁻³ It was determined that upper torso rotation as well as pelvic rotation were insignificant alone but together as the X-Factor separation, they are significant to ball velocity.^{2,3}

The first article examined multiple factors that were determined to be involved in producing a large angular velocity, which helps produce a greater distance: rapidly stretching hip, trunk and upper limb muscles during the backswing, and uncocking the wrists when the lead arm is about 30° below the horizontal. This review concludes that stability, Newton's laws of motion (inertia, acceleration, action reaction), lever arms, conservation of angular momentum, projectiles, the kinetic link principle and the stretch-shorten cycle are the important characteristics in proper golf biomechanics. Distance and accuracy will both be positively affected with proper biomechanics.¹

In a similar study by Myers,² the biomechanical role of the upper torso and pelvic rotation during driving velocity

were examined. Two different independent variables were measured: Upper torso rotation and pelvis rotation on the dependent variable of velocity, and torso-pelvic separation on the dependent variable of velocity. One-hundred recreational golfers were measured and the results found that torso-pelvic separation played the most significant role in maximizing ball velocity for the golfers. The authors suggest golfers should try to create a maximal separation between the upper torso and pelvis in order to achieve maximal ball velocity, therefore increasing distance.²

One study that measured the X-factor also measured other factors in the golf swing that other research had not measured. Delayed release of the arms and wrists, trunk forward and lateral tilting, and weight shifting during the swing were also analyzed in three-hundred and eight golfers. Chu, Sell, and Lephart³ found that trunk lateral bending, pelvis superior weight shift, and the X-Factor were found to be most critical in driving performance. Greater upward and backward rotation of the arms were also important in swing performance.³

The last study looked at different types of golf swing shots to determine the similarities and differences among kinematic proximal-to-distal sequencing and speed

summation. Partial and full swing shots were the independent variables measured. Forty-five golfers participated, eleven of which were male tournament professionals, and twenty-one male and thirteen female elite amateurs. Pelvis, upper torso, and hand movements were recorded. Results showed a proximal-to-distal temporal relationship as well as an increase in maximum angular velocity for both genders and in both shot conditions. This common proximal-to-distal sequencing will provide better mechanical and control points thus increasing the likelihood of improving speed and accuracy of both types of shots.⁴ This research could potentially provide insight as to how and when different segments in the upper body should be stretched during the warm-up.

Stretching Techniques Compared

Stretching as part of a general warm-up is a common occurrence among the active population whether it is directed by a knowledgeable health care professional or strictly based off of an individual's own beliefs. Three of the most commonly used stretching techniques and the three that will be examined in this review are static,

dynamic, and proprioceptive neuromuscular facilitation (PNF) stretching.⁵⁻³⁰

Static Stretching

The most common form of stretching is typically static stretching. This type of stretching technique involves no movement.¹⁸ The general thought behind static stretching is that it will increase flexibility, which will improve performance and provide less opportunity for injury. Contrary to popular belief, more recent research has begun to show that static stretching may have little or no affect on performance and may possibly even hinder performance.^{5-9,11,15,20,21,25,26}

The main idea behind any type of stretching is usually to improve range of motion. It is common practice for people to stretch before activity or just to improve flexibility. There has been a lot of research on the effects of static stretching on range of motion. Several studies have examined different areas of the body and came to the conclusion that static stretching significantly increases active and passive ranges of motion.^{5,6,19}

Another common idea of stretching is the thought that it will help enhance performance in some way or another. Static stretching is performed regularly prior to athletic

event but recent research is beginning to show this may not only be ineffective, but also may hinder performance.

Several articles assessed the effects of static stretching on muscular speed. Tests included measuring electromyography activity, movement time, reaction time, 10 yard sprint, agility drills, and clubhead speed.^{5,6,14,16-18,25-}

²⁷ There was not a single article that showed an improvement in movement speed. Most of the research results including a literature review by Janot,¹⁴ concluded no significant differences in performance.^{5,14,16-18, 27} Three articles on golf swing performance showed significant decreases in driver club head speed and ball velocity following a static stretching regimen.²⁵⁻²⁷

Maddigan's⁵ study looked at reaction time and movement time at the hip. Measurements were taken before and after a static stretching intervention. The subjects were thirteen active healthy adults; the six males were an average age of 24.6 years and the seven females averaged 23.7 years. The stretching protocol did significantly decrease angular velocity (movement time). The conclusion from this study was that athletes must take caution before competition because the possibility of impairment in limb strength and movement time may occur.⁵

A literature review by Janot, Dalleck, and Reymont¹⁴ compared the effects of static stretching vs. dynamic, ballistic, and PNF stretching techniques on performance and found no positive results for the static condition. Almost all of the articles that were reviewed showed all types of performance were either decreased or unchanged post-static stretch. When compared with the other three stretching techniques, static stretching showed no more effectiveness than any other stretch condition and it was concluded that other forms of stretching should be done instead of static prior to an event.¹⁴

A golf specific study completed by Gergley²⁵ measured the acute effects of a 20 minute full body static stretching routine followed by an active dynamic warm-up. The effects were measured on the dependent variables: clubhead speed, distance, accuracy, and consistent ball contact. There were 15 male competitive golfers studied with an average age of 20.6 years. After the warm-ups were completed the subjects were instructed to hit 10 full swing shots with a driver with 1 minute rest between each trial. The static stretch condition showed decreased driver performance in all dependent measures compared with a general active warm-up condition. This research suggests that full-body static stretching will be less effective

than an active, gradual warm-up routine before competition.²⁵

A second study was performed by Gergley²⁶ on the effects of a 20 minute full-body stretch routine followed by an active dynamic warm-up. This study measured the long-term effects on driver clubhead speed, distance, accuracy, and consistent ball contact. There were 9 male subjects used in this study with an average age of 20.4 years. They were instructed to hit 3 shots with their driver with a minute rest in between all three shots at intervals of 0, 15, 30, 45, and 60 minutes post-stretch. For the condition with the static stretch routine, distance and consistent ball contact showed a significant decrease in all five time intervals while clubhead speed and accuracy showed decreases, but recovered by the 45 minute and 60 minute intervals respectively. This suggested that static stretching prior to performance should be avoided and a more gradual active dynamic warm-up should be performed instead.²⁶

Golf swing performance with a 5 iron was also analyzed in another study by Moran.²⁷ Static stretching and no stretching interventions were compared as part of a general warm-up. Measurements were taken at 0, 5, 15, and 30 minutes after stretching. The subjects were eighteen male,

right-handed experienced golfers with a handicap of 6 or less, average age of 23.2 years. Both the static stretching and no stretching interventions produced no significant results in any of these conditions. It was concluded that a different form of stretching may be more effective than static in any golf warm-up to produce the best performance results.²⁷

Muscular power plays a critical role in athletic performance in some sports more than others. This is why a pre-performance stretching routine must be done properly in order for the athlete to achieve the best results possible. Articles that assessed muscular power used the following tests: vertical jump on a force platform, countermovement jump, drop jump, and medicine ball toss.^{6-8,11,16,17} Once again, like muscular speed, the effects of static stretching were found to be negligible or even detrimental to performance.^{6-8,11,16,17}

The objective of the article by Marek⁶ et al was to study the acute effects of static stretching peak torque and mean power output of the vastus lateralis and rectus femoris muscles. The measurements were recorded during voluntary maximal concentric isokinetic leg extensions at 60 and 300°·s⁻¹. The subjects were ten females with an average age of 23, and nine males with an average age of

21. At both measurements, peak torque and mean power output significantly decreased after the static stretch intervention. There were no positive significant changes found. The conclusion was that acute static stretching decreased muscular strength, power, and activation; however, the author did note the reader must weigh the risk-to-benefit ratio when using these stretching techniques because the change in muscle was small.⁶

Muscular power was assessed through vertical jump in a few studies measuring static stretching effects.^{7,11,17} The first of the three articles studied the acute effects of static stretching on vertical jump performance. A counter movement jump and a jump with no counter movement which was measured by a force plate were performed. Subjects were twenty-four men with an average age of 22.4 years. The results of this study showed the non-counter movement jump was unaffected; however, there was a significant decrease in the counter movement jump after static stretch. The authors concluded that static stretching has the potential to decrease performance acutely on vertical jump.⁷

The next article that assessed muscular power through vertical jump tested a secondary warm-up following stretching due to the idea that stretching commonly inhibited muscular performance. There were thirteen

participants; two females and eleven males age range from 18-28 years. Each participant completed a 5 min warm-up, followed by a vertical jump measured on a force platform. They then underwent one of the three interventions: static stretching, dynamic stretching, or no stretching. After the intervention they performed a second vertical jump followed by a series of movements. Finally, a third vertical jump was performed up to 60 min post activity. After the first intervention there was a 10.7% difference in static versus dynamic stretching conditions. After the second warm-up, vertical jump height showed no difference after the static stretch intervention. These results provided the conclusion that a secondary warm-up will most likely not reverse the detrimental acute effects of static stretching on performance.¹¹

The last study that used vertical jump as a measurement of muscular power found similar results as the other two researchers. Pre-activity static stretching was performed by thirty teenage athletes of about 15 years of age. The results showed no significant improvements in performance thus giving the conclusion that a static warm-up will be potentially less beneficial to performance than perhaps another form of stretching.¹⁷

In the last few articles that assessed static stretching on muscular power, several different dependent variables were studied. Countermovement jump, isometric time to peak knee extension, drop jump, and peak torque were measured.^{8,16} The results showed no significant differences between any variables, but that all performances had decreased after the stretching intervention.^{8,16}

Another systematic review by Kay and Blazevich studied pre-exercise stretching to determine whether there are decreases in post-stretch force and power. 106 articles were reviewed that met the inclusion criteria. The results showed that static stretches of less than 60 seconds were found to have no significant impacts while stretches greater than 60 seconds showed decrements in eccentric strength. This review determined that although no improvements were recorded, short-duration static stretching has little to no effect on maximal muscle performance.⁹

Despite stretching commonly being performed before exercise to enhance performance and reduce the risk of injury, there is limited scientific data to support the suggested benefits of stretching. Static stretching has been shown to have detrimental effects on muscle strength

and functional performances such as jumping, and to have inconclusive effects on the incidence of injury, and no effects on the severity of muscle damage.¹⁵

Of all the articles reviewed under the static stretching intervention, it is concluded by this author that static stretching is a great way to increase range of motion, however it may not be best used prior to performance. There was not a single article that showed any evidence of static stretching being the lone cause of an improvement in performance. Continued research may be needed to provide a more clear and concise agreement on the effects of static stretching, but this will provide a good base of evidence.

Dynamic Stretching

Another common form of stretching is dynamic stretching. Dynamic stretching consists of performing movements that take the limb through range of motion (ROM) by contracting the agonist muscles, which allows the antagonist muscles to relax and elongate due to reciprocal inhibition.³¹ As this type of stretching has become more common place in sport, more and more research is being performed to study its effects. Not only has most research found no detrimental effects to performance caused by

dynamic stretching, but it has also shown that it can increase performance as well.^{7,8,10,14,16-19,21,23,25-28}

Dynamic stretching has often been compared with static stretching and even proprioceptive neuromuscular facilitation stretching in much of the research. Only one article in this review covered both range of motion effects and performance effects caused by dynamic stretching. Silveira¹⁹ studied dynamic stretching on flexibility vs. static stretch and no stretch groups. Twelve participants performed the three interventions and it was reported that dynamic stretching not only improved dynamic flexibility but also static flexibility. The author concluded that dynamic stretching may be more effective for sport performance than static stretching alone.

Vanderka,⁷ Pearce,¹¹ and Yamaguchi²³ all performed similar research on dynamic stretching and muscular power. Vertical jump, countermovement jump, and leg extension power were the variables that were assessed.^{7,11,23} In the study by Vanderka, dynamic stretch before warm-up significantly increased performance in both the countermovement and the vertical jump.⁷ Pearce's study tested a secondary warm-up following stretching and also found that vertical jump height increased significantly after performing dynamic stretching.¹¹ Finally, Yamaguchi

measured leg extension power and found dynamic stretching significantly improved performance.²³

The idea in this review was to help determine whether a dynamic warm-up would improve performance more than static or PNF stretching in college athletes. Four studies were found that fit all the inclusion criteria. The research suggests there is moderate evidence to believe dynamic warm-ups will be more beneficial to performance than static or PNF stretching. Clinicians must be careful, however since all of the studies that were reviewed performed testing in a lab. This evidence may not transcend to a live event.¹⁰

A golf specific conditioning program was created by Fradkin, Sherman, and Finch²⁹ in order to determine its effectiveness immediately prior to performance as well as after being performed five times a week for five weeks. Clubhead speed was measured by 2D video analysis. The subjects participating were twenty male golfers that were matched by age and handicap. 10 underwent the conditioning program and 10 were in the control group. Results showed that clubhead speeds increased significantly in the testing group compared to the control group. The overall conclusion of this study is that golf performance is

enhanced by performing a golf specific warm-up compared to when not performing any warm-up.²⁹

Proprioceptive Neuromuscular Facilitation Stretching

A third form of stretching that is generally used more often in clinical settings than in sport settings is proprioceptive neuromuscular facilitation (PNF). This stretching technique uses proprioceptive, cutaneous, and auditory input to produce functional improvement in motor output and can be a vital element in the rehabilitation process of many conditions and injuries.³² PNF is controversial in the athletic population due to the fact that it can create positive effects, but also negative effects such as decreased force production or muscular speed. Acute range of motion increases have been shown by most research on PNF stretching, but it is suggested that all other benefits occur only if it is performed regularly.^{5,6,12,13,22}

Sharman¹³ focused specifically on the effects of proprioceptive neuromuscular facilitation stretching on range of motion. It was found that range of motion increases most after the first repetition of PNF, but to obtain a longer lasting increase in ROM, PNF stretching, like other types of stretching, needs to be performed at

least a couple times per week. Sharman concluded that PNF stretching is the most effective way of increasing range of motion alone acutely, however the heterogeneity of different PNF techniques must be examined to more accurately determine the best stretch to use.¹³

The goal of a literature review by Dale and Myers³⁰ was to look at proprioceptive neuromuscular facilitation stretching of the trunk because there had not been much research on this topic before. PNF has been found to positively affect sport-specific rehabilitation in other areas of the body. Two PNF patterns have been developed from this article: Chopping and lateral bending of the trunk simulate movement patterns similar to golf motions and help to stabilize the trunk for better performance in golf.³⁰

A second literature review also investigated the different physiological theories behind the effects of PNF. Four theories were determined to be the most reasonable mechanisms as to why PNF techniques affect range of motion. These theories include: autogenic inhibition, reciprocal inhibition, stress relaxation, and the gate control theory. This review concluded that PNF stretching decreases maximal strength performance when completed before exercise. When these techniques are preformed regularly as part of a

stretching routine, as well as post exercise, performance and range of motion have been shown to increase. The authors suggest that if the PNF techniques are performed correctly and adequately, there could be potential for many positive effects.¹²

The goal presented in the last study reviewed on PNF stretching compared its effects of high and low-volume static and PNF stretching on 1 repetition maximum bench press. 5 different stretching interventions were used as the independent variables: 1) non-stretching group, 2) low-volume PNF stretching 3) high-volume PNF stretching, 4) low-volume static stretching, and 5) high-volume static stretching. Subjects for this study were fifteen male NCAA DII football players average age 19.9 years. In all 5 conditions, the results showed no significant changes in performance of the 1RM bench press in these resistance trained football players. It was concluded that performance in already trained athletes is not significantly affected by PNF and static stretching.²⁸

The effects of stretching have been studied across a wide variety of different human movements involving the lower extremity. These studies examined the effects of static, dynamic, and PNF stretching techniques on different lower extremity tasks in order to create a generalized

consensus as to which should be used prior to athletic performance. In golf the lower extremity plays a big role in swing performance. The performance of a golf swing also involves a lot of upper body motion and this is why it is important to examine the effects that the aforementioned stretching techniques have on upper body performance, not only in golf but other activities involving similar muscle activity. After reviewing all of the literature on how stretching affects performance, a few conclusions have been made. All three types of stretching (static, dynamic, and PNF) can increase range of motion at least acutely. However, prior to performance dynamic stretching should be used for best results, and finally if proper rest is allowed prior to performance, static and PNF stretches can be used as well. In this study it was determined that proprioceptive neuromuscular facilitation would not be included due to its impracticality in a live situation on the golf course.

The Role of Balance in Golf

There are many different performance measures in the game of golf, some of which play more important roles than others. One performance measure that is often overlooked

in the sport is balance, especially in non-professional golfers because it is not easily observable. Balance is crucial to the success of any athletic movement, and the golf swing is no exception.³³ The fact that it plays an important role in golf creates the question as to why there is such little research on its role in the sport.

A study by Sell et al. looked at strength, flexibility, and balance in golfers to help determine the important physical characteristics in golf. The subjects in this study were 257 healthy male golfers age 45.5 +/- 12.8 years. They were split into three groups by handicap: 0, 1-9, and 10-20. Measurements were taken for strength and flexibility in the torso, shoulder, and hips, and balance was measured with a single-leg balance test on the right leg. The results found that the golfers with the lowest handicap (highest skill) had significantly greater strength and flexibility in the torso, shoulders and hips. They also had better single-leg balance (eyes open) scores for medial/lateral and anterior/posterior ground reaction forces. These results suggest that higher skilled golfers possess these important physical characteristics, balance specifically, that allow them to produce better shots than lower skilled golfers.²⁴

Stretching Effects on Balance

As reviewed above, stretching, whether static or dynamic has effects on performance. The purpose of this section is to determine whether either stretching condition will affect balance positively or negatively. Because balance plays a big role in golf swing performance, learning the effects of stretching could help guide a more logical warm-up for golfers.

A Body Basics article by Dylla and Forest³⁴ that focuses on the benefits from a daily static stretching routine lists several different benefits of stretching such as elongation of muscle which reduces imbalances and dysfunction, increased flexibility, circulation, and blood flow, postural improvements, as well as better balance and coordination. The article also demonstrates with pictures, how to perform stretches and for how long. The most commonly recommended regimen involves performing each stretch 1-3 times for 30 seconds at a time. This may show us that a regular and consistent static stretching routine may be beneficial for all golfers.³⁴

Behm et al³⁵ studied the effect of acute static stretching on force, balance, reaction time, and movement time of the lower extremity. Sixteen subjects were tested

pre and post static stretching of the quadriceps, hamstrings, and plantar flexors or after a similar duration for a control condition. The stretching followed a 5 minute bicycle warm-up. Each stretch was held for 45 seconds and had a 15 second rest period in between. A computerized wobble board was used to measure balance. It was found that acute bouts of static stretching actually impaired balance measures.³⁵

The last study by Costa et al³⁶ examined the effects of different durations of static stretching on dynamic balance. This study continued the last study discussed by Behm et al.³⁵ Twenty-eight women were tested for this study and underwent three different conditions, each one performed on separate days. There were two stretching conditions that were repeated 3 times with 15 seconds rest between and one control condition. One static stretch condition was held for 15 seconds while the second static stretch condition was held for 45 seconds but both used the same protocol as the study by Behm et al³⁵ stretching the quadriceps, hamstrings, and plantar flexors. A warm-up on an exercise bicycle was also performed prior to stretching. The control condition used the same warm-up but had a 26 minute rest period between both testing sessions. Balance was assessed using the Biodex Balance System. Testing

revealed that the 15-second condition produced a significant improvement in the balance scores whereas there were no significant effects with the control condition or the 45-second treatment. These results suggest that shorter duration stretching protocols may be more effective to improve balance and that longer duration protocols will most likely not affect balance.³⁶

Summary

Golf is a game of precision and like any other sport, the athletes that play the game are always looking for the best performance results possible. Almost all athletes warm-up prior to performance and this usually includes a stretching routine. The goal in this study was to determine which stretching routine would be best to perform prior to playing a round of golf. Acute static and proprioceptive neuromuscular facilitation stretching techniques showed little or no positive results in all studies while dynamic stretching showed positive effects on almost all performance measures. Balance was assessed to play an important role in golf performance and that better golfers tend to have better balance. With little research overall on the effects of stretching on balance, the few

studies that were examined showed mixed results. One study showed decreased balance ability after an acute bout of stretching while another showed improved balance. Another study showed a regular stretching routine can increase balance ability. These mixed results suggest there is need for further research on the topic and this thesis aims to find additional results in order to help guide golfers towards better performance.

APPENDIX B

The Problem

STATEMENT OF THE PROBLEM

For years, athletes of all different skill levels and in all different sports have employed stretching as part of their warm-ups prior to events or exercise. Certain sports, such as golf, require a more sport-specific warm-up due to the nature of the game. Golfers at the recreational and competitive levels have begun including stretching routines in their pre-event warm-ups in hopes of increasing their performance. Balance is a key component of golf and affecting it will affect performance. The purpose of this study is to determine the effects of different stretching interventions (static and dynamic) on balance during the performance of a golf swing to help guide golfers in the right direction before an event.

Definition of Terms

The following definitions of terms will be defined for this study:

- 1) Golf Swing - a full swing with a driver as if the participant were teeing off at a hole.
- 2) Confidence ellipse width - indicates the width of the ellipse in millimeters; the anterior/posterior sway of the subject's center of gravity.

- 3) Confidence ellipse angle - indicates the orientation of the direction of the longitudinal axis of the ellipse compared to the longitudinal (x/-) axis of the platform in degree and the orientation direction (left or right).
- 4) Confidence ellipse height - indicates the height of the ellipse in millimeters; the lateral sway of the subjects center of gravity.
- 5) Center of force horizontal and vertical deviation - the standard deviation and characterize the sway path width in millimeters.

Basic Assumptions

The following are basic assumptions of this study:

- 1) The subjects will be honest when they complete their demographic sheets.
- 2) The subjects will perform to the best of their ability during testing sessions.
- 3) The subjects will be above average in their golf skills.

Limitations of the Study

The following are possible limitations of the study:

- 1) This study is conducted in a controlled environment and may not simulate a typical round of golf.
- 2) The amount of subjects is limited to one university golf program.

Significance of the Study

There are a few reasons why this study may prove significant. It can provide golfers with a more specific and intelligent warm-up which can lead to possible improvements in performance. Another reason this study may be effective is that it will help prevent inadvertent performance decrements. This is because golfers will learn which stretches are positive and which stretches are negative towards their performance.

APPENDIX C
Additional Methods

APPENDIX C1

IRB: California University of Pennsylvania

From: instreviewboard <instreviewboard@calu.edu>
Subject: FW: IRB approval template 11-03-11
Date: February 11, 2013 4:15:00 PM EST
To: "GRO6497 - GROOSE, ADAM R" <GRO6497@calu.edu>
Cc: "West, Thomas" <west_t@calu.edu>

**Institutional Review Board
California University of Pennsylvania
Morgan Hall, Room 310
250 University Avenue
California, PA 15419
instreviewboard@calu.edu
Robert Skwarecki, Ph.D., CCC-SLP, Chair**

Dear Mr. Groose:

Please consider this email as official notification that your proposal titled "The effects of static and dynamic stretching on balance measures during the performance of a golf swing" (Proposal #12-029) has been approved by the California University of Pennsylvania Institutional Review Board as submitted.

The effective date of the approval is 2-11-2013 and the expiration date is 2-10-2014. These dates must appear on the consent form .

Please note that Federal Policy requires that you notify the IRB promptly regarding any of the following:

- (1) Any additions or changes in procedures you might wish for your study (additions or changes must be approved by the IRB before they are implemented)**
- (2) Any events that affect the safety or well-being of subjects**
- (3) Any modifications of your study or other responses that are necessitated by any events reported in (2).**
- (4) To continue your research beyond the approval expiration date of 2-10-2014 you must file additional information to be considered for continuing review. Please contact instreviewboard@calu.edu**

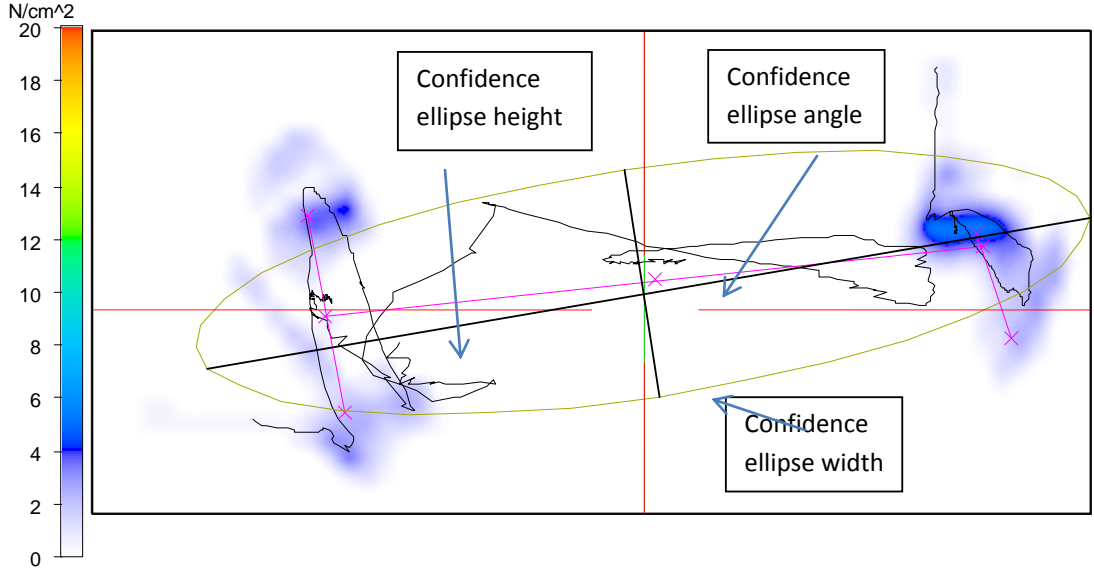
Please notify the Board when data collection is complete.

**Regards,
Robert Skwarecki, Ph.D., CCC-SLP
Chair, Institutional Review Board**

Appendix C2
Data Collection Sheet

Data Collection Example

Average Force Distribution



Parameters	25-02-2013 Static 1
Confidence ellipse width, mm	81.9
Confidence ellipse height, mm	316.1
Confidence ellipse angle, deg	81.6, right
Confidence ellipse area, mm*mm	20326.5
COF total track length, mm	1196.1
COF horizontal deviation, mm	127.8
COF vertical deviation, mm	38.1

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ABSTRACT

TITLE: The Effects of Static and Dynamic Stretching on Balance Measures during the Performance of a Golf Swing.

RESEARCHER: Adam Groose, ATC, PES

ADVISOR: Dr. Thomas F. West

PURPOSE: The purpose of this study was to examine the effects of static and dynamic stretching routines on different balance measures during the performance of a golf swing, to provide golfers with a better guide to a proper warm-up.

METHODS: Balance measures were recorded by the Science & Motion BalanceLab®. Subjects consisted of 19 males from the California University of Pennsylvania Professional Golf Management Program and golf team. Two separate days of testing occurred. On day 1, a static stretching routine was performed followed by 10 golf swings. On day 2, a dynamic stretching routine was performed followed by 10 golf swings. A driver of the subjects choice was used and there was a minute rest between each golf swing.

FINDINGS: Three different balance measures were recorded. No significant differences were found between the two stretching conditions in the balance measures of confidence ellipse width and height. A significant difference was found in the balance measure confidence ellipse angle. The dynamic stretching routine was found to have a significant effect on confidence ellipse angle.

CONCLUSION: After reviewing the results of this study, it cannot be accurately concluded as to which stretching routine is better prior to performance of a golf swing.