

CORRELATION BETWEEN PELVIC ROTATION AND GLUTEUS MAXIMUS  
STRENGTH IN GOLFERS

A THESIS

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

by  
Hyun Hong

Research Advisor, Dr. Thomas F. West

California, Pennsylvania  
2012

CALIFORNIA UNIVERSITY of PENNSYLVANIA  
CALIFORNIA, PA

THESIS APPROVAL

Graduate Athletic Training Education

We hereby approve the Thesis of

Hyun Hong, MA, ATC  
Candidate for the degree of Master of Science

Date

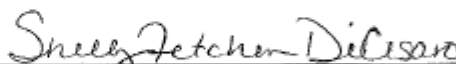
Faculty

5/10/2012



Thomas F. West, PhD, ATC (Chairperson)

5-2-12



Shelly Fetchen DiCesaro, PhD, ATC, CSCS

5-2-12



Justin D. Barroner, MS, PGA, PES, CGFI

## ACKNOWLEDGEMENTS

It's been a challenging year for me, but it has also been an amazing experience. My experiences at CalU have taught me the importance of research that will help me apply to a PhD program later. I would like to take the time to acknowledge some people whose support played a pivotal role in my accomplishments with this thesis.

Thank you for the NExt generation Sport Talent (NEST) for financially supporting and encouraging me to keep focusing on my study.

I would like to thank some others who have helped me to get where I am today. To everyone at University of Nebraska at Omaha where my interest in athletic training began, thank you. A special thanks to Dr. Melanie McGrath and classmate Yongha Seo.

I would like to thank my committee members, Dr. Thomas West, Dr. Shelly DiCesaro and professor Justin Barroner for all their time, revisions, and guidance to make my thesis a success.

I would like to thank all the people at CalU and California High School. We made the best of this year and I will always remember my time spent here. I would also like

to say thanks to all the GA's: Sean, Steve, Ted, Curt, Preston, Joey, Joe, Mark, Paul, Sarah, Atsuko and all the ladies. Thanks to Sean's family for the great times during Christmas and Easter.

Lastly, I cannot thank my parents enough for what they have done for me and graduation is only a tiny little bit of my appreciation for what they have done, so hopefully there's bigger things for them in the future and more things for us to share and celebrate. Your love and support has helped me accomplish all that I have. I love you mom and dad. I would also like to thank my brother and sister-in-law. You all mean a lot to me and thank for everything.

## TABLE OF CONTENTS

	Page
SIGNATURE PAGE . . . . .	ii
ACKNOWLEDGEMENTS . . . . .	iii
TABLE OF CONTENTS . . . . .	v
LIST OF TABLES . . . . .	viii
INTRODUCTION . . . . .	1
METHODS . . . . .	5
Research Design . . . . .	5
Subjects . . . . .	6
Preliminary Research. . . . .	7
Instruments . . . . .	8
Procedures . . . . .	10
Hypotheses. . . . .	13
Data Analysis . . . . .	13
RESULTS . . . . .	14
Demographic Data . . . . .	14
Hypothesis Testing . . . . .	15
Additional Findings . . . . .	18
DISCUSSION . . . . .	20
Discussion of Results . . . . .	20
Conclusions . . . . .	24
Recommendations. . . . .	26

REFERENCES . . . . .	28
APPENDICES . . . . .	30
APPENDIX A: Review of Literature . . . . .	31
Introduction . . . . .	32
Biomechanics of the golf swing . . . . .	32
Anatomy of the golf swing . . . . .	33
Modern and classic golf swing . . . . .	36
Spine motion in golfers with and without low Back pain . . . . .	38
The function of gluteus maximus muscle in golf .	39
Golf Swing stresses on the low back. . . . .	40
Weakness of the gluteus maximus muscle and the degree of pelvic rotation affect on low back pain . . . . .	43
Summary . . . . .	45
APPENDIX B: The Problem . . . . .	47
Statement of the Problem . . . . .	48
Definition of Terms . . . . .	48
Basic Assumptions . . . . .	49
Limitations of the Study . . . . .	49
Significance of the Study . . . . .	50
APPENDIX C: Additional Methods . . . . .	51
Informed Consent Form (C1) . . . . .	52
IRB: California University of Pennsylvania (C2) . .	56

Data Collection Sheet . . . . .	63
Subject Information Sheet . . . . .	65
Low Back Pain Questionnaire . . . . .	67
REFERENCES . . . . .	71
ABSTRACT . . . . .	74

## LIST OF TABLES

Table		Page
1	Intra-trial reliability of K-VEST at Top of Backswing	16
2	Intra-trial reliability of K-VEST at Impact	16
3	Inter-session reliability of Test 1 and 2	17
4	Correlation between GM strength and position	17
5	GM strength intra test reliability	19



## INTRODUCTION

Low back pain is the one of most common musculoskeletal complaints experienced by both amateur and professional golfers.<sup>1</sup> According to the National Golf Foundation's annual participation study,<sup>2</sup> the golfing population in the USA reached 27.1 million participants in 2009 which ranked the sport 16<sup>th</sup> among 41 activities and sports surveyed. The incidence of golf-related low back injury ranges from 15-34% in the amateur golfer and 22-24% in the professional ranks.<sup>3,4</sup>

There are many potential factors that can lead to low back pain and muscle imbalance is one of these factors. Almost every muscle in the body is used in some capacity during the golf swing. A weakness or deficiency in one area can alter biomechanics and impede the transfer of energy. The body compensates for this weakness by overusing other body parts in an attempt to make up for this lost energy. As a result, the area of weakness is placed under great stress and it leads to overuse injuries such as low back pain. According to Evans,<sup>5</sup> weakness of the abdominal muscles and weakness of gluteus maximus, or imbalanced muscles are commonly mentioned as major indicators of potential low

back pain.<sup>6</sup> The gluteus maximus is the largest muscle in the body and is important in many functional activities such as walking, running and lifting, and plays a role in pelvic stability.<sup>7</sup> Its location, connecting the lower extremity to the lumbar spine and pelvis, enables it to transfer forces between these two areas. Weakness of gluteus maximus muscle can lead to decreased transverse pelvic rotation and it may require more upper torso torque to compensate for lack of transverse motion during the golf swing.

Moreover, these days the majority of golfers tend to use a more modern swing than the classic golf swing in order to increase ball velocity and ball flight distance. As a result, the differential amount of separation between the shoulder and the pelvis tends to increase.<sup>8</sup> The modern golf swing emphasizes a large shoulder turn with a more restricted hip turn. The reduced hip turn is accomplished by keeping the front foot flat on the ground and maximizing the hip-shoulder separation angle throughout the swing.<sup>8</sup> On the other hand, the classic golf swing emphasizes reducing the hip-shoulder separation angle and this is accomplished by raising the front heel during the backswing to increase hip turn, shortening the back swing, or a combination of the two.<sup>8</sup> Hence, the increased separation of the modern swing represents increased strain in the spine and it

creates mechanical load on the lower back that may result in low back pain.<sup>1,8</sup>

While a number of classifications have been used to describe the phases of the golf swing, this study will divide the golf swing into five phases including backswing, acceleration, impact, early following through and late follow through. This study will primarily examine the degree of the upper and lower body separation at impact but will include the top of the golf backswing, and how this separation degree might be related to the low back pain scale.

It is further hypothesized that the degree of separation may be related to gluteus maximus strength, since the weakness of the gluteus maximus muscle may lead to inappropriate or inadequate transverse pelvic rotation during the golf swing, creating more upper torso torque. An inappropriate golf swing may produce significant stress on the body such as compression, anterior-posterior shearing, torsion and lateral bending forces on the lumbar spine, resulting in low back pain. Proper golf swing mechanics are one of the keys to decrease the heavy load on the low back area.

In order to accomplish this study, the separation between lower and upper degree and gluteus maximus strength

will be measured and correlated utilizing 3D motion capture and hand-held dynamometer. As a result, this study will provide evidence as to gluteus maximus muscle strength and its relationship to upper and lower body torsion degree during the golf swing.

## METHODS

The primary purpose of this study was to examine the relationship between shoulder-pelvic separation and gluteus maximus strength during the golf swing. This was done by comparing the degree of pelvic rotation and degree of shoulder rotation at the top of the golf backswing and at the moment of impact. Additionally this project determined the measures of pelvic and upper spine position utilizing a K-VEST wireless motion analysis system. Moreover, to measure gluteus maximus strength, a hand-held manual dynamometer was used. This description of research methods will include the following subsections: research design, subjects, instruments, procedures, hypotheses, and data analysis.

### Research Design

This research utilized a quasi-experimental design. Correlations between the variables were drawn from the data. Variables included degree of pelvic rotation and degree of shoulder rotation as measured by K-VEST wireless

motion analysis system and gluteus maximus strength as measured by a hand-held dynamometer. Reliability coefficients for the K-VEST wireless motion analysis system were also calculated.

### Subjects

20 golfers, between 18 and 34 years old, were selected randomly from volunteers. Following a brief introductory meeting the subjects were collected from the Professional Golf Management program, and athletes on California University of Pennsylvania men's and women's golf teams. Each subject was required to complete a low back pain questionnaire (Appendix C5) and a demographic questionnaire (Appendix C4) that provided information regarding age, weight and height. The subject inclusion and exclusion criteria were included: all subjects have consistently played golf 2 to 4 years minimum, and have a 12 handicap or lower. The subjects answered questions regarding how many 9 hole rounds of golf they play each month and how much time the subject practices the game of golf both on and off the golf course time increments include: 0-1, 2-4, 5-7, 8-10, or more than 10 hours each month.

Subjects have not had any orthopedic problems including lumbar degeneration, fracture or lumbar herniation. Moreover, the subjects have not had any previous history of orthopedic surgeries such as elbow, shoulder, back, knee and ankle. Furthermore, the subjects were free from neurological diseases and were not taking any medications that could affect performance.

An informed consent form (Appendix C1) was obtained from each subject that participated in the research study. The subjects read and signed the informed consent form before beginning any participation in the experiment. The subjects were recruited during a program meeting, upon approval from the Institutional Review Board (IRB) (Appendix C2) at California University of Pennsylvania was received.

#### Preliminary Research

A pilot study was conducted with this research project. Pilot study participants met all of the inclusion criteria as met by other participants. The subjects performed all of the testing procedures. The researcher was looking for the subject's ability to understand directions, the amount of time used to complete the tasks

and if the warm-up protocol before testing is adequate. Data was collected on the data collection sheet (Appendix C3).

### Instruments

The following instruments were used in this study: low back pain questionnaire, golf club, golf ball, golf simulator screen, Hand-held Dynamometer, and 3D motion capture

#### Golf Equipment

In order to be consistent for each subject, all subjects used a 5 iron golf club, a Callaway Hot® golf ball, golf simulator screen and the golfers performed each stroke.

#### Hand-held Dynamometer

A hand-held dynamometer, *Lafayette Instruments Model 01163*, used to measure gluteus maximus strength during manual muscle testing, and peak force was recorded for each trial. Although the hand-held dynamometer is not the most reliable device to measure muscle strength, the reliability of the device has been high.<sup>9-12</sup> The hand-held dynamometer provided muscle peak force in kg and the following formula



was calculated by normative strength compared to subject's weight. The distance was measured as the distance from Posterior Superior Iliac Spine (PSIS) to the center of popliteal. Conversions of data was made using the following formulas:

Newton's conversion:  $1\text{kg} = 9.81\text{N}$

$\text{Torque} = (\text{Force in Newtons}) \times (\text{distance in meters})$

$\text{Strength} = \text{Torque} / \text{Body weight in kilograms}$

### 3D Motion Capture

The K-VEST TPI 3D 4.1 technology is fully wireless, with three inertial sensors located on subject's hip, shoulder and glove/hand. The shoulder sensor was attached between T3 and T4 area, and hip sensor was attached to the Posterior Superior Iliac Spine (PSIS) area to make accuracy. The K-VEST works within the same software program that displays live video and animation in the same screen. Once a swing has been captured, the K-VEST analysis calculates 3D motion parameters including pelvis/thorax kinematic sequence, rotations, forward bend, side bend, and spine angle. Additionally, the collected data indicates as a red and green color bar easily highlighting which swing parameters are in or out of range at set-up, top of swing, and impact.

## Procedures

The study was approved by the California University of Pennsylvania Institutional Review Board (IRB) (Appendix C2) prior to any data collection. Professional golf management students and athletes on California University of Pennsylvania men's and women's golf teams were asked to volunteer to participate in this study during a brief meeting. The concept of the study was explained to the participants and the informed consent form (Appendix C1) was distributed for them to understand the need for and risks of involvement in the study. All subjects completed the informed consent forms before any testing or training took place. Qualifications for the subjects were also announced. The pre-screening tests were set up before the testing date was scheduled for each subject.

After the subjects understood and signed the informed consent form, the subjects completed the subject information sheet (Appendix C4) and the Low Back Pain Questionnaire form (Appendix C5). The researcher measured the subject's height and weight. The test procedure and method were explained again prior to beginning of the test session. All subjects did a warm up for approximately 5

minutes including 10 golf practice swings prior to participating in the 3D K-VEST TPI analysis. This warmup was the same as their standard pre-participation warmup.

While subjects warm up, the researcher set up measurement equipment. The 3D analysis sensors were attached via belts between the shoulder blades, on the posterior pelvis and hand via a glove, and the subjects were instructed to strike golf balls in the indoor golf course simulator until they felt comfortable. These practice swings allowed the subjects to become familiar with the apparatus and permitted the researcher to check the operation of the monitor. After the warm-up and check of the operation of the monitor to calibrate subject's standard position, the subjects were asked to swing three times into the golf simulator screen. In order to identify the reliability of the 3D K-VEST analysis system, the sensors were detached and reattached after first three golf swings. The subject's position was recalibrated and then performed three more golf swings. Each stroke was recorded using the K-VEST TPI 3D analysis system, and the average degree of pelvic torsion and degree of upper torsion were recorded for later use. After measuring the subject's golf swing, the subject had their gluteus maximus strength tested.

### Gluteus Maximus Strength Measurement

To measure gluteus maximus strength, subjects began by having their leg length measured by tape measure (Posterior Superior Iliac Spine to the center of popliteal space). The subject was asked to lay prone and slowly extend their test leg upward until contact was made with the hand-held manual dynamometer (*The Lafayette Manual Muscle Test System Model 01163*). To better isolate the gluteus maximus strength, the tested knee was maintained in a 90 degree flexed position during testing to minimize hamstring activation. While the subject performed the test, the researcher stabilized the subject's posterior pelvis and applied resistance to the posterior aspect of the distal femur with the hand dynamometer. The subject was instructed to push against the manual dynamometer for four seconds as hard as possible. This process was performed a total of three times, and average peak force measures was recorded for later use. Additionally, all subjects' weight and power were converted to Newtons. After gathering all the information about gluteus maximus strength, and angle between pelvic and shoulder position, the data was entered into a data analysis program (SPSS 18.0).

## Hypotheses

The following hypotheses were based on previous research and the researcher's intuition based on a review of the literature:

1. There will be a positive correlation between pelvic position and shoulder position measurements between individual trials and between the testing sessions.
2. There will be a positive correlation between gluteus maximus strength and shoulder-pelvic separation at the top of the golf backswing.
3. There will be a positive correlation between gluteus maximus strength and shoulder-pelvic separation at impact.

## Data Analysis

All data was analyzed by SPSS version 18.0 for windows at an alpha level of 0.05. The research hypotheses will be analyzed using the Pearson Product-Moment Correlation Coefficient analysis.

## RESULTS

The purpose of this study is to examine the relationship between shoulder-pelvic separation and gluteus maximus strength during the golf swing. This was done by comparing the degree of pelvic position and degree of shoulder position. A Pearson Product-Moment Correlation Coefficient analysis was applied to measure the correlation between shoulder-pelvic separation and gluteus maximus strength during the golf swing.

### Demographic Data

The sample for this study included 20 professional golf management students, 18 males and 2 females from California University of Pennsylvania. Ages ranged from 19 to 34 years with a mean of 21y (+/- 3.25). All participants were considered healthy by the low back pain questionnaire and reported no injuries throughout the study.

## Hypothesis Testing

The level of significance used for testing in this study was set at an alpha level of .05.

Hypothesis 1: There will be a positive correlation between pelvic position and shoulder position measurements between individual trials and between the testing sessions.

The first goal of this study was to examine the reliability of this equipment in measuring pelvic and shoulder position. Intra-trial and intersession reliability was examined.

In order to identify the intra-trial reliability of 3D motion capture, The Pearson-Product Moment Correlation was used to determine if there was a difference between the measurement of shoulder and pelvic position during the trials within each testing session. The Pearson correlation was calculated comparing all the three trials on test 1 and test 2 of the golf swing with 3D K-VEST TPI analysis system. Table 1 shows that there was a strong, statistically significant relationship between the trials of shoulder and pelvic separation at the top of back swing (Table 1). This indicates good intra-trial reliability of the K-Vest system.

**Table 1.** Intra-trial reliability of K-VEST at Top of Backswing

Trial	Shoulder		Pelvic	
	Test 1	Test 2	Test 1	Test 2
1-2	.985**	.972**	.978**	.950**
2-3	.969**	.951**	.957**	.956**
1-3	.942**	.973**	.953**	.956**

\*\* p&lt;.001

Generally lower reliability was found when measuring position of the pelvis and shoulders at impact. Specifically, strong, significant correlation coefficients were found for pelvic measures and a combination of strong and moderate significant correlations were found at the shoulders. Findings can be found in Table 2.

**Table 2.** Intra-trial reliability of K-VEST at Impact

Trial	Shoulder		Pelvic	
	Test 1	Test 2	Test 1	Test 2
1-2	.708**	.550 *	.942**	.928**
2-3	.483 *	.717**	.906**	.938**
1-3	.732**	.600**	.916**	.952**

\* p&lt;.05, \*\* p&lt;.001

Next the reliability of the 3D K-Vest TPI between test sessions was examined. Table 3 shows that the Inter-test session reliability of the K-VEST ranged from .678 to .930 dependent upon the site measured (pelvis or shoulders) and position (top of backswing or impact). Pelvic measurements at the top of the backswing demonstrated a strong correlation coefficient ( $r = .913$ ,  $p < .001$ ) as did measurements at impact ( $r = .930$ ,  $p < .001$ ). Measurements of the shoulders at impact also showed a strong correlation



( $r = .748$ ,  $p < .001$ ) while a moderate correlation was found at the top of the backswing ( $r = .678$ ,  $p < .001$ ).

**Table 3.** Inter-session reliability of Test 1 and 2

	<b>Top</b>	<b>Impact</b>
Shoulder	.678**	.748**
Pelvic	.913**	.930**

\*\*  $p < .001$

Hypothesis 2: There will be a positive correlation between gluteus maximus strength and shoulder-pelvic separation at the top of the golf backswing.

Table 4 indicates that a weak, non-significant correlation was found between the subject's gluteus maximus strength and pelvic torsion at the top of backswing ( $r = .237$ ,  $P > .05$ ). There was also a weak correlation between the subject's gluteus maximus strength and shoulder torsion at the top of backswing ( $r = -.222$ ,  $P > .05$ ). However, there was a moderate correlation between pelvic and shoulder separation with gluteus maximus strength at the top of backswing ( $r = .372$ ,  $P > .05$ ).

**Table 4.** Correlation between GM strength and position

	<b>TOP</b>	<b>Impact</b>
Pelvic Torsion	.237	.360
Shoulder Torsion	-.222	.277
Pelvic & Shoulder Separation	.372	.316

Hypothesis 3: There will be a positive correlation between gluteus maximus strength and shoulder-pelvic separation at impact.

Table 4 shows that the Pearson-Product Moment Correlation indicated a moderate correlation between gluteus maximus strength and pelvic torsion at impact ( $r = .360$   $P > .05$ ) while there was a weak correlation between gluteus maximus strength and shoulder torsion at impact ( $r = .277$ ,  $P > .05$ ). However, a moderate correlation between shoulder-pelvic separation and gluteus maximus strength have been shown at impact ( $r = .316$ ,  $P > .05$ ).

#### Additional Findings

Several studies have examined the reliability of the hand held dynamometer in testing strength. In order to identify the reliability of hand-held dynamometer in this study, the Pearson-Product Moment Correlation was calculated comparing all the three trials on test 1, test 2 and test 3 of the gluteus maximus strength. The Pearson Correlation demonstrated that there was a statistically significant relationship between each test (see table 5).

**Table 5.** GM strength intra test reliability

	<b>Test 1</b>	<b>Test 2</b>	<b>Test 3</b>
Test 1	1	.867**	.804**
Test 2	.867**	1	.938**
Test 3	.804**	.938**	1

\*\* p&lt;.001

## DISCUSSION

### Discussion of Results

This study examined the validity and reliability of the K-VEST TPI 3D motion analysis software program. This study considered the correlation between pelvic rotation and gluteus maximus strength with low back pain in golfers. However, all volunteer participants were in good health and were not suffering from low back pain as measured by the low back pain questionnaire.

Therefore, the hypotheses were focused more on reliability of the K-VEST 3D motion analysis, and correlation between gluteus maximus strength and the shoulder-pelvic separation. In other words, the study compared gluteus maximus strength with shoulder-pelvic separation at the top of backswing and at impact.

Hypothesis 1 stated that the shoulder and pelvic position measured with 3D motion capture would be reliable on subsequent trials. The researcher proposed that the results would not have significant variance between the

subsequent trials. This finding is important if the K-Vest is to be used in research.

There was statistically significant Intra-trial reliability of K-VEST 3D motion capture between at the top of backswing in both shoulder and pelvic position. However, the shoulder torsion measures had only moderate reliability at impact and top of the backswing in Intra-trial measures. Similar results were seen for the shoulder in inter-session testing, with the shoulder reliability being moderate and pelvic reliability as strong. It is considered that due to the wider range of motion and higher velocity of the shoulder when compared to the pelvis, the result of the shoulder torsion reliability indicates less reliability than pelvic torsion.

Even though a three-dimensional video motion analysis system would be the most reliable method to obtain range of motion measures, the K-VEST 3D motion capture also has been found to be a reliable and valid measure of joint separation. To improve the accuracy of data collection, however, it is recommended to consider utilizing multiple trials and averaging compensate for the moderate reliability of the K-Vest 3D during high speed, dynamic motions.

Hypothesis 2 stated that there is a positive correlation between gluteus maximus strength and shoulder-pelvic separation at the top of the golf backswing. The researcher proposed that the results would have significant correlation when comparing the gluteus maximus strength and shoulder-pelvic separation at the top of the golf backswing.

As discussed previously there was a weak correlation between gluteus maximus strength and both shoulder and pelvic torsion at the top of the golf backswing ( $r = .237$ ,  $r = -.222$  respectively). However, there was a moderate correlation between shoulder-pelvic separation and gluteus maximus strength at the top of backswing ( $r = .372$ ,  $P > .05$ ). This result may indicate a relationship between gluteus maximus strength and shoulder-pelvic separation at the top of the backswing but should be explored in future research.

According to McHardy and Pollard,<sup>14</sup> electromyographic studies on golf swing have demonstrated the most active muscle in the upper body is the upper trapezius on the right side while on the left side, subscapularis is the most active muscle. In contrast, the most active muscle in the lower body is the semimembranosus and the long head of the biceps femoris on the right side. The present study indicates that the gluteus maximus muscle seems to be

minimally activated during the backswing, which is the opposite expectation from the second hypothesis.

Hypothesis 3 stated that there is a positive correlation between gluteus maximus strength and shoulder-pelvic separation at impact.

The researcher proposed that the results would have correlation when comparing the gluteus maximus strength and shoulder-pelvic separation at impact. The result shows that there was a moderate correlation between shoulder-pelvic separation and gluteus maximus strength at the impact ( $r = .316$ ). Moreover, gluteus maximus strength has a moderate effect on pelvic torsion while there was a weak correlation between shoulder torsion and gluteus maximus strength. The result is almost similar to the top of the backswing. As a result, gluteus maximus strength seems to have an effect on the separation between pelvic and shoulder. In other words, when gluteus maximus strength is stronger, the separation between pelvic and shoulder seem to be wider than weak gluteus maximus strength during the golf swing.

According to McHardy and Pollard electromyographic studies on golf swing,<sup>14</sup> the most active muscles are upper and lower gluteus maximus on the right side during the forward swing which starts at the top of swing and ends when the club is horizontal to the ground. However, the left

biceps femoris, and the left upper and lower gluteus maximus are the most active muscles during the acceleration phase, which starts from the horizontal club to the impact of the ball.<sup>11</sup> Moreover, the abdominal oblique is the most active muscle, followed by the gluteus medius on the right side.<sup>11</sup> As a result, even though gluteus medius is the most active muscle during the acceleration phase, gluteus maximus has some influence on pelvic rotation, which may effect shoulder-pelvic separation.

### Conclusions

All participants were healthy by the low back pain questionnaire and reported no pain throughout the study. Thus, this study could not reveal the relationship between the degree of shoulder-pelvic separation and low back pain. This is certainly something to be included in future studies.

The results of the study revealed the following two major conclusions. First, K-VEST TPI 3D motion analysis software program and the hand-held manual dynamometer are reliable tools to determine the degree of shoulder-pelvic rotation, and gluteus maximus strength respectively. Moreover, the K-VEST and hand-held manual dynamometer are



inexpensive tools when compared to other 3D motion capture systems and strength evaluation tools like a Biodex. These two devices are easy to use, making them ideal for the clinical setting and performance enhancement setting.

Second, there is a moderate correlation between shoulder-pelvic separation and gluteus maximus strength at the top of the backswing and at impact. These results suggest that strong gluteus maximus strength contributes to increase shoulder-pelvic separation (at the top the swing and at impact).

From this study it can be concluded that K-VEST TPI 3D motion analysis can be applied to study the quality and quantity of golf swing motions in separation degree. Moreover, this study shows a moderate relationship existed between gluteus maximus strength and increased shoulder-pelvic separation at the top of the swing and at impact. This means that in order to create greater torque and transferring a higher velocity to a club, shoulder-pelvic separation seems to increase with strong gluteus maximus group.

## Recommendations

Based on the results of this study, the following research recommendations were made. The K-VEST 3D motion capture and hand-held manual dynamometer have been found to produce reliable measurements. Despite the strong reliability of the 3D motion capture, it is possible that reliability could be further increased if the analysis sensors were more firmly attached to the subject's body during the golf swing. Therefore, the pelvis and shoulder sensors should be checked after every single trial of the golf swing to increase the quality of measures. For instance, the shoulder sensor should be repositioned between T3 and T4 area and the hip sensor repositioned on the PSIS area after each swing.

Moreover, although the hand-held manual dynamometer was the reliable methods to measure gluteus maximus strength, the researcher should maintain the subject's knee in a 90 degree flexed position and stabilize the subject's posterior pelvis to get better isolate the gluteus maximus strength. Moreover, it would be better to have an assistant to stabilize the subject's pelvis, to allow for the researcher to use both hands to hold the hand-held manual dynamometer rather than one.

Lastly, the subjects who participate in this study were in a good health so future research should further test patients who have low back pain or a history of low back pain. This would allow for an examination of the role that separation angle may play in increasing low back stress and pain in the golfing population.

## REFERENCES

1. McHardy A, Pollard H, Bayley G. A comparison of the modern and classic golf swing: a clinician's perspective. *SAJSM*. 2006;18(3): 80-92.
2. Beditz B, Kass AR. Golf participation America, 2010-2020. *National Golf Foundation*. 2009;1-8.
3. Levine D, Walker JR, Tillman LJ. The effect of abdominal muscle strengthening on pelvic tilt and lumbar lordosis. *Physiotherapy Theory and Practice*. 1997;(12): 217-226.
4. Mchardy A, Pollard H. Lower back pain in golfers. *Journal of Chiropractic Medicine*. 2005;(4): 135-143.
5. Horan SA, Evans K, Morris NR, Kavanagh JJ. Thorax and pelvis kinematics during the downswing of male and female skilled golfers. *Journal of Biomechanics*. 2010;(43): 1456-1462.
6. Franke BA. Formative Dynamics: The Pelvic Girdle. *The Journal of Manual & Manipulative Therapy*. 2003;11(1):12-40.
7. Willson J, Ferris E, Heckler A, Maitland L, Taylor C. A structured review of the role of gluteus maximus in rehabilitation. *New Zealand Journal of Physiotherapy* . 2005;3(33): 95-100.
8. Gluck GS, Bendo JA, Spivak JM. The lumbar spine and low back pain in golf: a literature review of swing biomechanics and injury prevention. *The Spine Journal*. 2008;(8): 778-788.
9. Fenter PC, Bellew JW, Pitts TA, Kay RE. Reliability of stabilized commercial dynamometers for measuring hip abduction strength: a pilot study. *British Journal of Sports Medicine*. 2003;37:331-334.
10. Kolber MJ, Beekhuizen K, Cheng MSS, Fiebert IM. The reliability of hand-held dynamometry in measuring isometric strength of the shoulder internal and

external rotator musculature using a stabilization device. *Physiotherapy Theory and Practice*. 2007;23(2):119-124.

11. Friel K, McLean N, Myers C, Caceres M. Ipsilateral Hip Abductor Weakness After Inversion Ankle Sprain. *Journal of Athletic Training*. 2006;41(1):74-78.
12. Hollman JH, Kolbeck KE, Hitchcock JL, Koverman JW, Krause DA. Correlations Between Hip Strength and Static Foot and Knee Posture. *Journal of Sport Rehabilitation*. 2006;15:12-23.
13. Burden AM, Grimshaw PN, Wallace ES. Hip and shoulder rotations during the golf swing of sub-10 handicap players. *Journal of Sports Sciences*. 1998;16:165-176.
14. McHardy A, Pollard H, Bayley G. A comparison of the modern and classic golf swing: a clinician's perspective. *SAJSM*. 2006;18(3): 80-92.

## APPENDICES

## APPENDIX A

## Review of Literature

## REVIEW OF LITERATURE

Several prevention and rehabilitation of low back pain protocols have been developed for the non-operative treatment of patients with low back pain. However, baseline differences between treatment groups, such as different types of sport may require different prevention strategies. Additionally, the best treatment for low back pain is prevention of the injury in the first place. Therefore, the purpose of this literature review is to focus on 1) biomechanics of the golf swings, 2) how the golf swing stresses the low back, and 2) how weaknesses of gluteus maximus muscle and the degree of pelvic rotation affect low back pain.

### Biomechanics of the Golf Swing

Low back pain is one of the most common golfing injuries, representing in 26 % to 52% of all complaints.<sup>1</sup> The repetition of a golf swing can create forces on the spine, exposing it to hyperextension, anterior-posterior shearing, torsion, and lateral bending.<sup>2</sup> Therefore, certified athletic trainers and other clinicians must have



an understanding of biomechanics of the golf swings in order to prevent athletes from potential low back injuries.

### Anatomy of the Golf Swing

While a number of classifications have been used to describe the phases of the golf swing, in this thesis, the golf swing is divided into five phases including backswing, forward swing, acceleration, early follow through and late follow through.

First, the back swing starts from when the club starts movement to the top of the back swing with most backswing motion results from shoulder and pelvic rotation. During the backswing of a right-handed golfer, the upper trapezius and the middle trapezius muscles are the most utilized muscles on the right upper body causing scapular retraction, while subscapularis and upper serratus muscles are the most activated muscles on the left upper body, protracting the scapula.<sup>3</sup> In contrast, the semimembranosus and the long head of the biceps femoris on the right lower body cause the back swing motion, and erector spinae and abdominal oblique on the left lower body are the most utilized muscles in the lower body resulting in the back swing motion as well.

Second, the forward swing, which initiates the downward motion of the club, starts at the top of the swing

and ends when the club is horizontal to the ground. Most importantly during the forward swing phase, on the right leg hip extensor and abductors, and the left leg adductor magnus initiate left pelvic rotation during the golf swing.<sup>4</sup> In other words, the left pelvic rotation starts before the arms have completed the backswing.<sup>4</sup> During the forward swing phase, the most active muscles are rhomboid and middle trapezius in the upper body on the left side while the most active muscles are the pectoralis major and upper serratus on the right side.<sup>11</sup> In contrast, during the forward swing phase the lower gluteus maximus and the biceps femoris are most activated, 100% and 98% respectively measured by manual muscle strength testing on the right side of the lower body.<sup>3</sup> On the left side, vastus lateralis and the adductor magnus muscle are most activated during the forward swing phase.<sup>3</sup>

Third, the acceleration phases starts from the club reaching horizontal to the club head impact with the ball. In this stage of the swing, the pectoralis major muscle bilaterally being the most active muscle in the upper body.<sup>3</sup> In the lower body, the left biceps femoris is the most active muscle with the left upper and lower gluteus maximus, along with the vastus lateralis being the second most

active muscles.<sup>3</sup> On the right side, the abdominal oblique is the most active muscle followed by the gluteus medius.<sup>3</sup>

Fourth, the early follow through phase starts at impact to when the club is horizontal to the ground. During this phase, pectoralis major bilaterally, subscapularis and infraspinatus muscles are most active on the left upper body.<sup>3</sup> The most active muscle in the lower body is left long head of biceps femoris, and left vastus lateralis.<sup>3</sup> The right gluteus medius and abdominal oblique muscles are the most active on the right side.<sup>3</sup>

Last, the late follow through phase starts from at impact to the ends of the completion of the swing. The purpose of this phase is to decelerate the body by using eccentric muscle actions.<sup>32</sup> The infraspinatus and the pectoralis major muscles in the left upper body are most utilized during the late follow through while subscapularis and serratus anterior muscles are most active on right side.<sup>3</sup> In the lower body, the right gluteus medius and the vastus lateralis are the most active muscles on right side while the semimembranosus and vastus lateralis are the most active muscles on left side during the late follow through.<sup>3</sup>

### Modern and Classic Golf Swing

Proper golf swing mechanics is one of the keys to decrease the heavy load on the low back area. An inappropriate golf swing seen in amateur golfers imparts significant stress such as compression, anterior-posterior shearing, torsion, and lateral bending forces on the lumbar spine. Without knowledge of the proper swing mechanics, golfers are exposed to the risk for the development of low back pain.

There are many different types of the golf swing, and the "modern" golf swing and the "classic" golf swing are most common in these day. The "modern" golf swing emphasizes a large shoulder turn with a restricted hip turn. Reduced hip turn is accomplished by keeping the front foot flat on the ground throughout the swing.<sup>6</sup> This is thought to "quiet" the lower body, and maximizing the hip-shoulder separation angle in order to increase the viscoelastic elements and increase rotational velocity.<sup>6</sup> This separation angle is known as the "X-factor" due to the "X" made by lines drawn along the axial orientation of the shoulders and hips at the transition between the end of the backswing and start of the forward swing.<sup>6</sup> Lindsay and Horton<sup>23</sup> performed a swing analysis between 12 golfers with and without low back pain to look for an association between

the "X-factor" and low back pain by focusing on trunk rotation. They found that there was no significant difference in peak rotation between the groups during their golf swing. However, "X-factor" produces the instantaneous side bend angle and axial rotation velocity which contributes to the degenerative changes in the lumbar spines during the golf swing.<sup>7</sup>

Another high-risk motion causing the low back pain during the modern swing is the "reverse C" position. During the follow through phase, there is an increase in lateral bending and exaggerated hyperextension on the spine known as the "reverse C" position. A line drawn from the right heel along the leg, up the pelvis and trunk to the left shoulder and head resembles the line drawn by a backwards 'C'.<sup>1</sup> These relative "X-factor" and "reverse C" position may represent excessive strain on viscoelastic structure in the spine beyond their physiologic range of flexibility.<sup>6</sup>

On the other hand, the classic golf swing emphasizes reducing the "X-factor" and this is accomplished by raising the front heel during the backswing to increase hip turn, shortening the back swing, or a combination of the two.<sup>6</sup> This reduces the magnitude of the hip-shoulder separation angle, and it decreases the torque on the lumbar spine.<sup>6</sup> Despite the advantage of "classic swing" for decreasing the

risk of low back problems, most golfers tend to prefer the "modern" swing due to power and greater potential for golf ball distance.<sup>6,8,9</sup>

According to Myers<sup>9</sup> and Fletcher<sup>10</sup>, "X-factor" could result in eccentric loading of the torso musculature through lengthening. This eccentric loading can play an important role in increasing ball velocity through both increasing uncoiling (torso-pelvic separation velocity) and upper torso rotational velocity during the down swing.<sup>9</sup>

#### Spine Motion in Golfers With and Without Low Back Pain

Although there was no significant difference in address position spinal posture between the golfers with and without low back pain, the golfers with low back pain tended to address the ball with considerably more spinal flexion than the golfers without low back pain. Spinal flexion for golfers with low back pain was  $37.0 \pm 11.4^\circ$  and  $25.3 \pm 6.6^\circ$  for participants without low back pain.<sup>11</sup>

Although there were no significant flexion angle difference, increased lumbar disc pressure and risk of injury could contribute to low back pain from golf. Interestingly, by subtracting the start (address position) flexion from the maximum (downswing) flexion, it would appear that spinal flexion of the golfers without low back pain increased by

just over 25° on the downswing compared with just 7° for the golfers with low back pain.<sup>11</sup> However, both groups of golfers showed that the trunk maintained a consistent angle with the ground throughout the entire backswing and downswing.<sup>11</sup> Lindsay and Horton<sup>7</sup> found that although the golf swing maximum rotation angles did not vary between the two groups, maximum rotation range of motion was more restricted in the group with low back pain. The low back pain group had less trunk rotation which resulted in a relative 'supramaximal' rotation of their spines when swinging and it could contribute to ongoing irritation of the spinal structures.

#### The Function of Gluteus Maximus Muscle in Golf

Gluteus maximus is the largest muscle in the body and is important in many functional activities such as walking, running and lifting, and plays a role in pelvic stability.<sup>12</sup> Wilson<sup>12</sup> describes the insertion of gluteus maximus proximally into the sacrum, the dorsal sacral ligaments, the posterior portion of the crest of the ilium and the sacrotuberous ligament. The muscle fibers run inferiorly and laterally to the distal insertion, where it splits in two components.<sup>12</sup> The upper half of the muscle inserts into the iliotibial tract of the fascia lata and the lower half

into the gluteal tuberosity of the femur.<sup>12</sup> Due to its attachments, gluteus maximus is primarily involved in external rotation and extension of the hip joint. Especially during the forward swing phase in the lower body, upper and lower gluteus maximus muscles initiate left pelvic rotation and create upper body torsion. Moreover, the lower gluteus maximus is the most activated muscles during the forward swing phase measured by manual muscle strength testing on the right side of the lower body with a right-handed player.<sup>13</sup>

#### Golf Swing Stresses on the Low Back

The current teaching philosophy of the golf swing emphasizes an increase in torso coiling during the backswing, which theoretically results in increased impulse during the downswing, and subsequent increased ball velocity and ball flight distance.<sup>9</sup> These days, professional golfers seem to maximize upper torso rotation during the backswing while minimizing pelvic rotation to create torso-pelvic separation (modern swing style). The separation creates resistance between the upper torso and pelvis during the backswing, and increases the viscoelastic elements and increase rotational velocity during the down



swing. As a result of torso uncoiling power, potentially increase club head speed, ball velocity, and therefore increasing the ball flight distance.

According to Fletcher and Hartwell,<sup>10</sup> the action of the torso can be classified as a stretch-shortening movement that utilize eccentric loading to load the muscle during the back swing in order to increase power output and explore concentric shortening during the forward swing. The stretch-shortening results in increased force and power production. According to Myers,<sup>9</sup> maximum separation between upper torso-pelvic tends to increase ball velocity. However, the repetitive stretch-shortening produces the instantaneous side bend angle and axial rotation velocity which contributes to the degenerative changes in the lumbar spines. The lumbar spines allow significant flexion and extension with moderate lateral bending, but relatively little axial rotation. Often many golf instructors put emphasis on loading the lumbar spine and creating tremendous amounts of torque to increase ball velocity.<sup>6</sup> According to "Non-operative Treatment of LBI in athletes",<sup>14</sup> the most frequent cause of acute low back pain was the limited range of axial rotation in the lumbar spine and the emphasis on torsional loading during the golf swing. Those poor golf mechanisms may potentially predispose a golfer to

muscle strains, herniated nucleus pulposus, stress fractures of the vertebral body and pars interarticularis, spondyloisthesis, and facet arthropathy.<sup>6,15</sup>

One side of repetitive play and practice may also contribute asymmetric pattern of trunk rotation and may cause side-to-side muscle imbalances in rotational strength. These potential imbalances may create shear and compressive loads on the lumbar spine and results in an increased susceptibility of developing low back pain.<sup>16</sup> According to Lindsay<sup>16</sup>, elite player group and recreational player group showed that a slight and consistent trend in muscle asymmetry was noticed in both groups. Additionally, low back pain group were observed to have greater gluteus maximus strength differences in side-to-side strength than without low back pain group.<sup>17,18</sup> Moreover, the muscle imbalance may contribute to limited hip-rotation range of motion (ROM). For example, limited hip-rotation ROM resulting from shortened muscles might contribute to compensatory movement in the lumbopelvic region. This limited ROM constantly contribute to low-magnitude loading of the lumbopelvic region and accumulation of tissue stress over time and cause tissue damage during the golf swing.<sup>19</sup> Additionally, an asymmetry in hip-rotation ROM would result in an asymmetry in the forces transmitted to the

lumbopelvic region.<sup>19</sup> Study showed <sup>19,20</sup> that the low back pain group demonstrated less total hip-rotation passive range of motion than the group without low back pain. Also the low back pain group indicated that the total rotation between left and right lower extremities was less total hip-rotation ROM than the group without a history of low back pain group.<sup>19</sup>

#### Weakness of the Gluteus Maximus Muscle and the Degree of Pelvic Rotation Affect on Low Back Pain

The movement of a golfer's swing requires mostly movement in the transverse plane. Many muscles help pelvic rotation during a golf swing, and the gluteus maximus is one of the strongest external rotators and extension of the hip joint. It has been theorized that weakness of the gluteus maximus may lead to increase tension in the low back and may cause SI joint instability that can create low back pain.<sup>2</sup> Moreover, the weakness of the gluteus maximus muscle may lead to inappropriate transverse pelvic rotation during a golf swing and it may create more upper torso torque which may cause stress on low back area.

According to the Willson<sup>12</sup> gluteus maximus provides sacroiliac joint (SIJ) stability, strength for lifting,

control of gait and transversal plane movement. There is very little movement at the SIJ which is the primary function of load transfer from the trunk to legs. If excess and abnormal movement occur at the joint, a positional change may occur between the ilia and sacrum thus compromising the L5-S1 intervertebral joints and disc, SIJ, pubic symphysis and could lead to SIJ dysfunction and low back pain.<sup>12</sup>

Limited or excessive hip joint range of motion may be one of the predisposing factors in musculoskeletal pain syndromes of the trunk. These dysfunctional ROM patterns may cause deleterious cumulative stress or strain on soft tissue and bones of the spine. For example, limited hip-rotation range of motion resulting from shortened muscles, a stiff joint capsule, or a bony abnormality might contribute to compensatory movement in the lumbopelvic region.<sup>19</sup> Such compensation could result in the lumbopelvic region's moving more often during activities that require hip rotation, such as the golf swing.<sup>19</sup> Thus, Harris-Hayes<sup>19</sup> found that limited hip rotation ROM was significantly correlated with low back pain. In theory, asymmetry of pelvic rotation ROM and any loss of rotation at the hip may place excessive mechanical stress on the lumbar spine, and lead to low back dysfunction because of the anatomical

proximity of the hip and lumbopelvic region.<sup>20</sup>

Cole<sup>21</sup> showed that golfers with low back pain tended to demonstrate reduced lumbar erector spinae (ES) activity at the top of the backswing and at the impact phase and greater the external obliques (EO) activity throughout the swing. The reduced ES and increased EO may be associated with a reduced capacity to protect the spine and its surrounding structures at the top of the backswing and at impact, where the torsional loads are high.<sup>27</sup> While, the weakness of gluteus maximus strength and the increase in upper body rotation may lead to increase spine angle during the impact phase. Weakness of gluteus maximus which leads to decrease hip ROM and the increase in upper body rotation during at the impact phase may lead to increase spine angle, and the increased spine angle will lead to the excessive mechanical stress on the lumbar spine and cause low back pain.

#### Summary

After studying the biomechanics of the golf swing in relation to the lumbar spine, it is understandable how both acute and chronic injuries can occur and how they can be prevented. There is no one master key to reduce low back

pain but low back pain may be minimized with appropriate management.

Proper strength training, increasing rotational flexibility, knowledge of biomechanics, understanding the anatomy of the golf swing and learning different types of swing mechanics have all been shown to be beneficial in decreasing potential low back pain in golfers.

## APPENDIX B

## The Problem

## STATEMENT OF THE PROBLEM

The purpose of the study is to examine the effect of gluteus maximus strength and degree of pelvic rotation on chronic low back pain in golfers. It is important to examine this correlation because weakness of gluteus maximus strength may reduce transverse pelvic rotation and it may create stress on the low back area. If we know gluteus maximus strength can interact with pelvic rotation and it creates low back pain, we can enhance the gluteus maximus strength in order to prevent chronic golfer's low back pain. Additionally it would be beneficial for athletes, conditioning coaches and athletic trainers to know which types of exercises are most effective in enhancing gluteus maximus strength.

### Definition of Terms

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

- 1) Gluteus maximus - The gluteus maximus is the largest and most superficial of the three gluteal muscles. It makes up a large portion of the shape and appearance of the buttocks. It has the power to maintain the



trunk in the erect posture and it also helps powerful external rotation and extension of the hip joint.

- 2) Transverse pelvic rotation - motion of the pelvic girdle on right transverse (clockwise) and left transverse (counterclockwise) rotation.

### Basic Assumptions

The following are basic assumptions of this study:

- 1) The subjects will be honest when they complete their pain level questionnaire sheets.
- 2) The subjects will perform to the best of their ability during the testing sessions.
- 3) Patients playing more than 5 years have not had any orthopedic problems including lumber degeneration, fracture and lumbar herniation.
- 4) The subjects have not had any previous history of surgery, and all are free from neurological diseases and are not taking any pain medications.

### Limitations of the Study

The following are possible limitations of the study:

- 1) The validity of the pain level has not been established.
- 2) The subjects can use different types of golf swings.

- 3) Motions of the knee can influence pelvic rotation during the golf swing.
- 4) Subjects may have different levels of flexibility resulting in different separation measures.
- 5) The cumulative load theory (the total number of hours worked for more hours over their lifetimes, and high force activity.<sup>22</sup>
- 6) Warm-up: subjects were allowed to choose their own warm-up.

#### Significance of the Study

If gluteus maximus strength has strong influence on pelvic transverse plane during the golf swing and the degree may be related to low back pain. Therefore, clinician, educator and related population can add gluteus maximus exercise on their conditioning training or rehabilitation in order to prevent or decrease low back pain.

## APPENDIX C

## Additional Methods

APPENDIX C1

Informed Consent Form

1. Hyun Hong, a certified athletic trainer, who is a Graduate Athletic Training Student at California University of Pennsylvania, has requested my participation in a research study at California University of Pennsylvania. The title of the research is *Correlation Between Pelvic Rotation, Gluteus Maximus Strength and Low Back Pain in Golfers*.

2. I have been informed that the purpose of this study is to provide evidence as to correlation between rotation and muscle strength during a golf swing. Specifically the researcher will look at upper and lower body separation and gluteus maximus strength, and its relationship to low back pain. I understand that I must be 18 years of age or older to participate. I understand that I have been asked to participate because I do not have orthopedic problems that affect my ability to participate in golf, including lumbar degeneration, fracture and lumbar herniation, also I do not have any general health problems that affect my golf participation. Moreover, I have not had any previous history of orthopedic surgeries such as surgery to the elbow, shoulder, back, knee and/or ankle. Furthermore, I do not have any neurological diseases or I am not taking any medications that may affect my participation.

3. I have been invited to participate in this research project. Participation is voluntary and I can choose to discontinue my participation at any time without penalty or loss of benefits. Subjects in this study will perform a golf swing and have their gluteus maximus strength measured. My height, weight and leg length will be measured and I will answer the Low Back Pain Questionnaire form. All subjects will perform their typical warm up followed by 10 golf practice swings utilizing a 5 iron. The 3D analysis system called K-VEST TPI 3D will be attached on subject's hip, shoulder and glove. After the warm-up, the subjects will use a 5 iron to hit a golf ball (Callaway Hot) three times into the simulator. Each stroke will be recorded using the K-VEST TPI 3D analysis. After measuring subject's golf swing, the subject will have their gluteus maximus strength tested.

To measure gluteus maximus strength, subjects will begin by having their leg length measured. A marker will be placed halfway down the posterior aspect of hamstring. The subjects will be asked to lay prone (face down) on a table and slowly extend their test leg upward until contact will be made with the hand-held dynamometer (a device to measure strength). The subject will be instructed to push against the manual dynamometer for four seconds as hard as

possible. This process will be performed a total of three times, and average peak force measures will be recorded for later use.

4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. With participation in a research program such as this there is always the potential for unforeseeable risks as well. There are minimal risks to the subjects in this study. The warm-up I will perform is the same as my standard warm-up prior to golfing. The golf swings are the same as I do during normal participation in the sport. Still, as with any physical activity, there is a risk of musculoskeletal injury, including muscle strains and joint sprains. The researcher will be present through the entire warm-up, measurement and testing phases within the study. The researcher is certified in first aid, CPR and as an athletic trainer. Subjects will be instructed in proper technique prior to all testing. Each test will be performed under the close supervision of the researcher. Improper technique or other potential injury-causing situations will be identified and corrected by the researcher to ensure that such injuries do not occur. In the case of injury the investigator will care for and treat the injured subject using the facilities available at the California University of Pennsylvania. Any treatment beyond that rendered by the investigator will be my financial responsibility.

5. I understand that, in case of injury, I can expect to receive treatment or care in Hamer Hall's Athletic Training Facility. This treatment will be provided by the researcher, Hyun Hong, under the supervision of the Calu athletic training faculty, all of which can administer emergency care. Additional services needed for prolonged care will be referred to the attending staff at the Downey Garofola Health Services located on campus. Costs associated with treatment will be my responsibility.

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

7. I understand that the possible benefit of my participation in the research is to understand the function of gluteus maximus strength during the golf swing and how the correlation between gluteus maximus strength and separation between upper and lower body angle and its effects on low back pain. This study can help golf coaches and golfers decide whether to add gluteus maximus exercises to a golf training program to reduce possible low back pain.

8. I understand that the results of the research study may be published but my name or identity will not be revealed. Only aggregate data will be reported. In order to maintain confidentiality of my records, Hyun Hong will maintain all documents in a secure location on campus and password protect all electronic files so that only the student researcher and research advisor can access the data. Each subject will be given a specific subject number to represent his or her name so as to protect the anonymity of each subject.

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

10. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by Hyun Hong MA, ATC [hon0718@calu.edu](mailto:hon0718@calu.edu) 423 Wood St. California, PA 15419, (540)686-6979 and Thomas F. West PhD, ATC, California University of Pennsylvania, [west\\_t@calu.edu](mailto:west_t@calu.edu), 250 University Ave California, PA 15419, (724) 938-5933

11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

12. I have read the above information and am electing to participate in this study. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

13. This study has been approved by the California University of Pennsylvania Institutional Review Board.

14. The IRB approval dates for this project are from: 01/01/2012 to 12/31/2012.

Subject's signature: \_\_\_\_\_

Date: \_\_\_\_\_

Witness signature: \_\_\_\_\_

Date: \_\_\_\_\_

Approved by the California University of Pennsylvania IRB

APPENDIX C2

Institutional Review Board -  
California University of Pennsylvania





California University  
of Pennsylvania

Proposal Number

Date Received

PROTOCOL for Research Involving  
Human Subjects

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

*(Reference IRB Policies and Procedures for clarification)*

**Project Title** CORRELATION BETWEEN PELVIC ROTATION, GLUTEUS MAXIMUS STRENGTH AND LOW BACK PAIN IN GOLFERS

**Researcher/Project Director** Hyun Hong

**Phone #** 540-686-6979

**E-mail Address** hon0718@calu.edu

**Faculty Sponsor (if required)** Thomas F. West

**Department** Health Science

**Project Dates** January 1 2012 to December 31 2012

**Sponsoring Agent (if applicable)** N/A

**Project to be Conducted at** California University o Pennsylvania

**Project Purpose:**  Thesis  Research  Class Project  Other

**Keep a copy of this form for your records.**

**Please attach a typed, detailed summary of your project AND complete items 2 through 6.**

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

This study will measure gluteus maximus strength and upper/lower body separation degree during the golf swing in skilled golfers. Instruments used to take these measures will include a hand-held dynamometer and 3D analysis system called the K-Vest TPI 3D. Volunteer subjects for this study will include members of the CalU men's and women's golf team and students enrolled in the Professional Golf Management Program. All subjects regularly golf and have golfing handicaps of 12 or better.

Measurements will be recorded during two testing sessions with testing identical on both days so that reliability measures can be determined for the instruments utilized. All subjects will warm up for 5 minutes including 10 golf practice swings prior to participating in 3D K-VEST TPI analysis. This warmup will be similar to their standard preparticipation warmup. The 3D analysis sensors will be attached via belts between the shoulder blades, on the posterior pelvis and hand via a glove, and the subjects will be instructed to strike golf balls in the indoor golf course simulator until they feel comfortable. After the warm-up and check of the operation of the monitor, the subjects will swing three times into the golf simulator screen. Each stroke will be recorded using the K-VEST TPI 3D analysis system, and average degree of pelvic rotation and degree of upper torsion will be recorded for later use. After measuring subject's golf swing, the subject will have their gluteus maximus strength tested.

To measure gluteus maximus strength, subjects will begin by having their leg length measured. A marker will be placed halfway down the posterior aspect of hamstring to adjust for center of gravity. The subjects will be asked to lay prone and slowly extend their test leg upward until contact will be made with the hand-held dynamometer (The Lafayette Manual Muscle Test System Model 01163). To better isolate the gluteus maximus strength, the tested knee will be maintained in a 90 degree flexed position during testing to minimize hamstring activation. While the subject performs the test, the researcher will stabilize the subject's posterior pelvis and apply resistance to the posterior aspect of the distal femur with the hand dynamometer positioned on the marker. The subject will be instructed to push against the manual dynamometer for four seconds as hard as possible. This process will be performed a total of three times, and average peak force measures will be recorded for later use. Additionally, all the data of the subject's weight and power will be converted to Newtons. After gathering all the information about gluteus maximus strength, and angle between pelvic and upper, the data will be entered into a data analysis program (SPSS 18.0). All tests will be taken approximately 20 minutes.

Subjects will repeat this same testing procedure on Day 2 of testing.

There are three hypotheses for this study

1. There will be a positive correlation between gluteus maximus strength and pelvic transverse plane rotation at impact.
  2. There will be a negative correlation between pelvic rotation and upper torsion degree at impact.
  3. There will be a positive correlation between the difference in pelvic rotation/upper torsion degree and low back pain.
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.*

There are minimal risks to the subjects in this study. All subjects golf regularly as they are either members of the golf team or students in the Professional Golf Management program. The warm-up they will perform is similar to their standard warm-up. The golf swings are the same as they do during normal participation in the sport. Still, as with any physical activity, there is a risk of musculoskeletal injury, including muscle strains and joint sprains. The researcher will be present through the entire warm-up, measurement and testing phases within the study. The researcher is certified in first aid, CPR and as an athletic trainer. Subjects will be instructed in proper technique prior to all testing and warm-up exercises. Each test will be performed under the close supervision of the researcher. Improper technique or other potential injury-causing situations will be identified and corrected by the instructor to ensure that such injuries do not occur. In the case of injury the investigator will care for and treat the injured subject using the facilities available at the California University of Pennsylvania. Subject anonymity will be maintained throughout the study through the use of subject numbers and not names.

- 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.*

Approximately 20 volunteers between 18 and 25 years old who consistently play golf with a 12 handicap or under will be collected from the Professional Golf Management (PGM) students at California university of Pennsylvania as well as athletes on California University of Pennsylvania men's and women's golf teams. Subjects will be attained through a volunteer basis for participation. Announcements at team meetings and PGM classes will be made to recruit subjects, subject participation will be free from coercion from coaches or faculty members.

- 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.*

A brief meeting will be held where the subjects will be able to read a written copy of the informed consent, ask any questions, sign the consent form, etc. Each signed form will be kept in a file by the researcher and the names of the subjects will be checked on a list as they are completed and turned in. The subjects who do not complete the form will not be included in the study and also the subjects may withdraw from the research at any time if they feel not comfortable during any participation in the experiment.

- 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.*

All data and consent forms will be collected and recorded by the researcher and will be kept in a locked file in the Graduate Athletic Training Education Program Director's office in Hamer Hall. Only the researcher and research advisor will have access to the records. Subjects will only be identified by number, names will not be recorded. Once the data is entered into electronic media, the files will be stored in a password protected file on University servers.

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

- |  |  |
|--|--|
| <input checked="" type="checkbox"/> <i>Adult volunteers</i>        | <input type="checkbox"/> <i>Mentally Disabled People</i>           |
| <input checked="" type="checkbox"/> <i>CAL University Students</i> | <input type="checkbox"/> <i>Economically Disadvantaged People</i>  |
| <input type="checkbox"/> <i>Other Students</i>                     | <input type="checkbox"/> <i>Educationally Disadvantaged People</i> |
| <input type="checkbox"/> <i>Prisoners</i>                          | <input type="checkbox"/> <i>Fetuses or fetal material</i>          |
| <input type="checkbox"/> <i>Pregnant Women</i>                     | <input type="checkbox"/> <i>Children Under 18</i>                  |
| <input type="checkbox"/> <i>Physically Handicapped People</i>      | <input type="checkbox"/> <i>Neonates</i>                           |

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.
7. If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix \_\_\_ in the Policies and Procedures Manual.

**Project Director's Certification**  
Program Involving HUMAN SUBJECTS

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

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

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


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

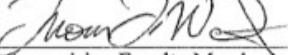
**Professional Research**


\_\_\_\_\_  
Project Director's Signature

\_\_\_\_\_  
Department Chairperson's Signature

**Student or Class Research**

  
\_\_\_\_\_  
Student Researcher's Signature

  
\_\_\_\_\_  
Supervising Faculty Member's  
Signature if required

  
\_\_\_\_\_  
Department Chairperson's Signature

**ACTION OF REVIEW BOARD** (IRB use only)

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

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

Approved [ \_\_\_\_\_ ]

Disapproved

\_\_\_\_\_  
Chairperson, Institutional Review Board

\_\_\_\_\_  
Date

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

Dear Hyun Hong:

Please consider this email as official notification that your proposal titled "Correlation between pelvic rotation, gluteus maximus strength and low back pain in golfers" (Proposal #11-031) has been approved by the California University of Pennsylvania Institutional Review Board as amended.

The effective date of the approval is 2-28-2012 and the expiration date is 2-27-2013. 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 2-27-2013 you must file additional information to be considered for continuing review. Please contact [instreviewboard@calu.edu](mailto:instreviewboard@calu.edu)

Please notify the Board when data collection is complete.

Regards,

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

## APPENDIX C3

## Data Collection Sheet

## Data Collection Sheet

Subject #	Gluteus Maximus Strength (GMS)			Leg Length
	1	2	3	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				



APPENDIX C4

Subject Information Sheet

## Subject Information Sheet

Subject # \_\_\_\_\_ (For Researcher's Use Only)

Demographic Questionnaire

Age \_\_\_\_\_ Gender M F

Height \_\_\_\_\_ cm Weight \_\_\_\_\_ kg Leg Length \_\_\_\_\_ cm

Year in College \_\_\_\_\_

- 1) PGM Student / Golf teams at Calu \_\_\_\_\_
- 2) What is your handicap? \_\_\_\_\_ OR what is your average 9 hole score? \_\_\_\_\_
- 3) Are you currently taking golf lessons? (at least 3 times per year) \_\_\_\_\_
- 4) Have you ever used video or 3D swing analysis equipment? \_\_\_\_\_
- 5) Did/do you play golf competitively (high school team, junior tournaments, etc...)?  
\_\_\_\_\_
- 6) Are you routinely participating in any physical training or exercise?  
(at least 2 times per week, for 30 minutes each session)  
If so, what type? (body building, core strength, flexibility training, cardio,  
endurance, etc) \_\_\_\_\_
- 7) How many total years of experience do you have playing golf?  
2-4 ( ), 5-7 ( ), 8-10 ( ), More than 10 years ( )
- 8) How many 9 hole rounds of golf you play each month? ( )
- 9) How much time do you practice the game off of the golf course each month  
0-1 ( ), 2-4 ( ), 5-7 ( ), 8-10 ( ), More than 10 hours ( )

APPENDIX C5

Low Back Pain Questionnaire

## Oswestry Low Back Pain Disability Questionnaire

---

Sources: Fairbank JCT & Pynsent, PB (2000) The Oswestry Disability Index. *Spine*, 25(22):2940-2953.  
Davidson M & Keating J (2001) A comparison of five low back disability questionnaires: reliability and responsiveness. *Physical Therapy* 2002;82:8-24.

The Oswestry Disability Index (also known as the Oswestry Low Back Pain Disability Questionnaire) is an extremely important tool that researchers and disability evaluators use to measure a patient's permanent functional disability. The test is considered the 'gold standard' of low back functional outcome tools <sup>[1]</sup>.

### Scoring instructions

For each section the total possible score is 5: if the first statement is marked the section score = 0; if the last statement is marked, it = 5. If all 10 sections are completed the score is calculated as follows:

Example:        16 (total scored)  
                      50 (total possible score) x 100 = 32%

If one section is missed or not applicable the score is calculated:

                      16 (total scored)  
                      45 (total possible score) x 100 = 35.5%

Minimum detectable change (90% confidence): 10% points (change of less than this may be attributable to error in the measurement)

### Interpretation of scores

<b>0% to 20%: minimal disability:</b>	The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting sitting and exercise.
<b>21%-40%: moderate disability:</b>	The patient experiences more pain and difficulty with sitting, lifting and standing. Travel and social life are more difficult and they may be disabled from work. Personal care, sexual activity and sleeping are not grossly affected and the patient can usually be managed by conservative means.
<b>41%-60%: severe disability:</b>	Pain remains the main problem in this group but activities of daily living are affected. These patients require a detailed investigation.
<b>61%-80%: crippled:</b>	Back pain impinges on all aspects of the patient's life. Positive intervention is required.
<b>81%-100%:</b>	These patients are either bed-bound or exaggerating their symptoms.

## Oswestry Low Back Pain Disability Questionnaire

### Instructions

This questionnaire has been designed to give us information as to how your back or leg pain is affecting your ability to manage in everyday life. Please answer by checking ONE box in each section for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement which most clearly describes your problem.

#### Section 1 – Pain intensity

- I have no pain at the moment
- The pain is very mild at the moment
- The pain is moderate at the moment
- The pain is fairly severe at the moment
- The pain is very severe at the moment
- The pain is the worst imaginable at the moment

#### Section 2 – Personal care (washing, dressing etc)

- I can look after myself normally without causing extra pain
- I can look after myself normally but it causes extra pain
- It is painful to look after myself and I am slow and careful
- I need some help but manage most of my personal care
- I need help every day in most aspects of self-care
- I do not get dressed, I wash with difficulty and stay in bed

#### Section 3 – Lifting

- I can lift heavy weights without extra pain
- I can lift heavy weights but it gives extra pain
- Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently placed eg. on a table
- Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned
- I can lift very light weights
- I cannot lift or carry anything at all

#### Section 4 – Walking\*

- Pain does not prevent me walking any distance
- Pain prevents me from walking more than 2 kilometres
- Pain prevents me from walking more than 1 kilometre
- Pain prevents me from walking more than 500 metres
- I can only walk using a stick or crutches
- I am in bed most of the time

**Section 5 – Sitting**

- I can sit in any chair as long as I like
- I can only sit in my favourite chair as long as I like
- Pain prevents me sitting more than one hour
- Pain prevents me from sitting more than 30 minutes
- Pain prevents me from sitting more than 10 minutes
- Pain prevents me from sitting at all

**Section 6 – Standing**

- I can stand as long as I want without extra pain
- I can stand as long as I want but it gives me extra pain
- Pain prevents me from standing for more than 1 hour
- Pain prevents me from standing for more than 3 minutes
- Pain prevents me from standing for more than 10 minutes
- Pain prevents me from standing at all

**Section 7 – Sleeping**

- My sleep is never disturbed by pain
- My sleep is occasionally disturbed by pain
- Because of pain I have less than 6 hours sleep
- Because of pain I have less than 4 hours sleep
- Because of pain I have less than 2 hours sleep
- Pain prevents me from sleeping at all

**Section 8 – Sex life (if applicable)**

- My sex life is normal and causes no extra pain
- My sex life is normal but causes some extra pain
- My sex life is nearly normal but is very painful
- My sex life is severely restricted by pain
- My sex life is nearly absent because of pain
- Pain prevents any sex life at all

**Section 9 – Social life**

- My social life is normal and gives me no extra pain
- My social life is normal but increases the degree of pain
- Pain has no significant effect on my social life apart from limiting my more energetic interests eg, sport
- Pain has restricted my social life and I do not go out as often
- Pain has restricted my social life to my home
- I have no social life because of pain

**Section 10 – Travelling**

- I can travel anywhere without pain
- I can travel anywhere but it gives me extra pain
- Pain is bad but I manage journeys over two hours
- Pain restricts me to journeys of less than one hour
- Pain restricts me to short necessary journeys under 30 minutes
- Pain prevents me from travelling except to receive treatment

\*Note: Distances of 1 mile, ½ mile and 100 yards have been replaced by metric distances in the Walking section

## REFERENCES

1. McHardy A, Pollard H, Bayley G. A comparison of the modern and classic golf swing: a clinician's perspective. *SAJSM*. 2006;18(3): 80-92.
2. Nourbakhsh MR, Arabloo AM, Salavati M. The relationship between pelvic cross syndrome and chronic low back pain. *Journal of Back and Musculoskeletal Rehabilitation*. 2006;19:119-128.
3. McHardy A, Pollard H. Muscle activity during the golf swing. *British Journal of Sports Medicine*. 2005;39:799-804.
4. Bechler JR, Jobe FW, Pink M, Perry J, Ruwe PA. Electromyographic analysis of the hip and knee during the golf swing. *Clinical Journal of Sport Medicine*. 1995;5(3):162-6.
5. Pink M, Perry J, Jobe FW. Electromyographic analysis of the trunk in golfers. *American Journal of Sports Medicine*. 1993;21(3):385-388.
6. Gluck GS, Bendo JA, Spivak JM. The lumbar spine and low back pain in golf: a literature review of swing biomechanics and injury prevention. *The Spin Journal*. 2008;(8): 778-788.
7. Lindsay D, Horton J. Comparison of spine motion in elite golfers with and without low back pain. *Journal of Sports Sciences*. 2002;20: 599-605.
8. Hume PA, Keogh J, Reid Duncan. The Role of Biomechanics in Maximising Distance and Accuracy of Golf Shots. *Sports Medicine*. 2006;35(5): 429-449.
9. Myers J, Lephart S, Tsai YS, Sell T, Smoliga J, Jolly J. The role of upper torso and pelvis rotation in driving performance during the golf swing. *Journal of Sports Sciences*. 2008;26(2):181-188.
10. Fletcher IM, Hartwell M. Effect of an 8-Week Combined Weights and Plyometrics Training Program on Golf Drive Performance. *Journal of Strength and Conditioning Research*. 2004;18(1):59-62.

11. Lindsay D, Horton J. Comparison of spine motion in elite golfers with and without low back pain. *Journal of Sports Sciences*. 2002;20: 599-605.
12. Wilson J, Ferris E, Heckler A, Maitland L, Taylor C. A structured review of the role of gluteus maximus in rehabilitation. *New Zealand Journal of Physiotherapy* . 2005;3(33): 95-100.
13. Levine D, Walker JR, Tillman LJ. The effect of abdominal muscle strengthening on pelvic tilt and lumbar lordosis. *Physiotherapy Theory and Practice*. 1997;(12): 217-226.
14. Chilton MD, Nisenfeld FG, Nonoperative Treatment of Low Back Injury in Athletes. *Clinics in Sports Medicine*. 1993;12(3):547-555.
15. Reed JJ, Wadsworth LT. Lower Back Pain in Golf: A Review. *American College of Sports Medicine*. 2010;9(1):57-59.
16. Lindsay DM, Horton JF, Trunk Rotation Strength and Endurance in Healthy Normals and Elite Male Golfers with and without Low Back Pain. *North American Journal of Sports Physical Therapy*. 2006;1(2);80-89.
17. Nadler SF, Malanga GA, Feinberg JH, Prybicien M, Stitik TP, DePrince M. Relationship Between Hip Muscle Imbalance and Occurrence of Low Back Pain in Collegiate Athletes. *American Journal of Physical Medicine & Rehabilitation*. 2001; 80(8): 572-577.
18. Brody DM, Running Injuries; Prevention and Management. *The original Clinical Symposia on Running Injuries*. 1980;32(4):2-36.
19. Harris-Hayes M, Sahrman SA, Van Dillen LR. Relationship Between the Hip and Low Back pain in Athletes Who Participate in Rotation-Related Sports. *Journal of Sport Rehabilitation*. 2009;18:60-75.
20. Ellison JB, Rose SJ, Sahrman SA. Patterns of Hip Rotation Range of Motion: A Comparison Between Healthy Subjects and Patients with Low Back Pain. *Physical Therapy*. 1990;70(9):537-541.



21. Cole MH, Grimshaw PN. Electromyography of the trunk and abdominal muscles in golfers with and without low back pain. *Journal of Science and Medicine in Sport*. 2008;11:174-181.
22. Kumar S. Theories of Musculoskeletal Injury Causation. *Ergonomics*. 2001;44(1):17-47.

## ABSTRACT

Title: CORRELATION BETWEEN PELVIC ROTATION AND GLUTEUS MAXIMUS STRENGTH IN GOLFERS

Researcher: Hyun Hong

Advisor: Dr. Thomas F. West

Data: May 2012

Research Type: Master's Thesis

Purpose: The purpose of this study is to examine the relationship between shoulder-pelvic separation and gluteus maximus strength during the golf swing.

Problem: It is important to examine the correlation between gluteus maximus strength and transverse plane pelvic rotation as it may create stress on the low back area during the golf swing. If we know gluteus maximus strength is related to pelvic rotation we can enhance the gluteus maximus strength in order to prevent or decrease a golfer's low back pain.

Method: Twenty subjects from California University of Pennsylvania participated in K-VEST 3D motion analysis of a golf swing. A Pearson Product-Moment Correlation Coefficient analysis was applied to measure the correlation between shoulder-pelvic separation and gluteus maximus strength during the golf swing. Moreover, a hand-held manual dynamometer was used to measure gluteus maximus strength.

Findings: The K-VEST TPI motion analysis and hand-held dynamometer were found to be both a reliable and valid measure of shoulder-pelvic separation and gluteus maximus strength respectively.