

**Pathomechanics in Lumbopelvic
Movement in Professional Golfers with
Limited Hip Internal Rotation**

Solbi Kim

The Graduate School of Health and Environment

Yonsei University

Department of Ergonomics Therapy

**Pathomechanics in Lumbopelvic
Movement in Professional Golfers with
Limited Hip Internal Rotation**

A Master's Thesis

**Submitted to the Department of Ergonomic Therapy
and the Graduate School of Health and Environment,
Yonsei University in partial fulfillment of the
requirements for the degree of
Master of Science**

Solbi Kim

June 2012

This certifies that the Master's thesis
of Solbi Kim is approved.

Thesis Supervisor: Sunghyun You

Thesis Committee Member#1: Chunghwi Yui

Thesis Committee Member#2: Ohyun Kwon

The Graduate School of Health
and Environment, Yonsei University

June 2012

Acknowledgments

*“Give thanks to the Lord, call on his name;
make known among the nations what he has
done. Glory in his holy name; let the hearts
of those who seek the Lord rejoice.”*

1 Chronicles 16:8, 10

This work would not have been completed without help and support of many individuals.

I would like to thank everyone who has helped me along the way.

This thesis is dedicated to my lovely parents, family, friends,

faculty members, colleagues and Dr.Yoon-hee Chang

for their love, endless support

and encouragement.

Table of Contents

Acknowledgements	i
List of Figures	v
List of Tables	vi
Abstract	vii
INTRODUCTION	1
Purpose of study	3
Definitions	4
Abbreviations	5
Research Hypotheses	6
METHODS	7
1. Experimental Study Design	7
2. Participants	7
2.1 Inclusion/Exclusion Criteria	8
2.2 Clinical Measurements	8
2.2.1 Hip Joint Internal and Lateral Rotation Motion	8
2.2.2 FABER Test	9
3. Setting	9

4. Variables	9
5. Experimental Instrumentation	10
5.1 Motion Analysis System	10
5.2 Digital Goniometer	12
5.3 Biodex and Handheld Dynamometer	13
6. Procedures	14
6.1 Motion Analysis	14
6.2 Flexibility Test	16
6.3 Strength Test of Trunk Muscles and Hip Rotators	17
7. Data Analysis	18
8. Statistical Analysis	19
RESULTS	20
1. Demographic and Anthropometric Data	20
2. Clinical Test Data	21
2.1 Muscle Length Test Data	21
2.1.1 Passive SLR Test Data	21
2.1.2 Thomas Test Data	22
2.2 Muscle Strength Test Data	23
2.2.1 Trunk Flexor and Extensor Strength Data	23
2.2.2 Hip Rotators Strength Data	24
3. Kinematic Parameters	26

3.1 Lumbar Kinematics	26
3.2 Pelvis Kinematics	29
3.3 Hip Kinematics	32
3.4 Correlation Analysis	34
DISCUSSION	35
CONCLUSIONS	40
REFERENCES	41
ABSTRACT IN KOREAN	48

List of Figures

Figure 1. Mimetic diagram of motion analysis system	11
Figure 2. Three-dimensional biomechanical analysis of the golf swing	11
Figure 3. Digital goniometer	12
Figure 4. Biodex system III	13
Figure 5. Handheld dynamometer	13
Figure 6. Six critical events of the golf swing	15
Figure 7. Comparison of knee flexion angle between 2 groups	21
Figure 8. Comparison of hip flexion angle between 2 groups	22
Figure 9. Comparison of lumbar motion angle between two groups in each phase	28
Figure 10. Comparison of pelvis motion angle between two groups in each phase	31
Figure 11. Comparison of hip motion angle between two groups during golf swing	33

List of Tables

Table 1. Abbreviations	5
Table 2. Description of 6 analyzed swing points	15
Table 3. Demographic and anthropometrical characteristics of participants	20
Table 4. Isokinetic strength for trunk muscles	23
Table 5. Isometric strength of hip rotators and ratio between group	25
Table 6. Comparison of lumbar motion angle between two groups in each phase	27
Table 7. Comparison of pelvis motion angle between two groups in each phase	30
Table 8. Pearson's correlation analysis in all subjects	34

ABSTRACT

Pathomechanics in Lumbopelvic Movement in Professional Golfers with Limited Hip Internal Rotation

Solbi Kim

Dept. of Ergonomic Therapy

The Graduate School of

Health and Environment

Yonsei University

Limited range of hip motion may cause lumbopelvic movement faultiness during a golf swing. We investigated the kinematics of the lumbo–pelvic–hip complex in golfers with limited internal rotation of the hip during a golf swing. Of the 30 male professional golfers who participated in this study, 15 showed limited internal motion in the lead hip (LHIM; $<20^\circ$), whereas the other 15 participants had normal internal motion in the hip (NHIM; $>30^\circ$). The kinematics of the lumbar spine, pelvis, and hip were assessed using 3-dimensional motion analysis with 8 infrared cameras. Passive straight leg raise and Thomas test were performed to determine the lengths of the hamstring and iliopsoas

muscles. Trunk muscle strength was tested using the Biodex System, and isometric hip rotator force for both legs was measured using a portable handheld dynamometer. A 2-tailed independent t-test was used to compare the mean differences in the kinematic parameters, trunk flexor/extensor strength, hip rotator strength, and hamstring flexibility between the 2 groups. Because iliopsoas flexibility data did not show normal distribution, Mann–Whitney test was used to compare the Thomas test values between the 2 groups. Correlation analysis was performed to identify the relationship between passive hip rotation range of motion (ROM) and maximum pelvis rotation angle during a golf swing. Statistical significance was set at $p < 0.05$. Golfers with LHIM had significantly shorter right-leg hamstrings ($p = 0.000$) and iliopsoas ($p = 0.017$) than did golfers with NHIM. Trunk strength was similar in the 2 groups. However, LHIM golfers exhibited less strength in the trail hip external rotator ($p = 0.024$) and lead hip internal rotator ($p = 0.001$) than the NHIM golfers. Kinematics showed that the lumbar rotation angle was significantly higher in LHIM golfers than in NHIM golfers at the top of backswing ($p = 0.000$), follow-through ($p = 0.012$), and finish phase ($p = 0.020$) of a golf-swing cycle. The lumbar right side bending angle was also significantly higher in LHIM than in NHIM golfers at the impact ($p = 0.016$) and finish phases ($p = 0.003$). Compared to golfers with NHIM, those with LHIM showed significantly high lumbar flexion angles ($p = 0.000$) at the address, top of backswing, acceleration, and impact phases. The range of pelvis rotation was significantly lower in LHIM than in NHIM golfers at the follow-through and finish phases ($p = 0.000$). The pelvis anterior tilt was significantly high in LHIM than in NHIM golfers at the top of backswing ($p = 0.041$); however, in the acceleration phase,

golfers with LHIM had significantly greater posterior tilt of pelvis than the controls ($p = 0.021$). Golfers with LHIM had a significantly smaller left hip internal rotation angle than golfers with NHIM at the finish phase. Pearson's correlation test revealed a positive relationship between the left hip internal rotation ROM and left pelvic rotation ($r = 0.603$; $p = 0.000$). On the contrary, left hip external rotation ROM was negatively correlated with the left pelvic rotation ($r = -0.441$). Our results suggest that professional golfers with limited internal hip rotation have hip rotator strength imbalance and muscle shortness (hamstring and iliopsoas) at the hips, which contributes to altered lumbopelvic movements and is a potential risk factor for low back pain.

Key Words: Golf, Limited hip rotation, Low back pain, Lumbopelvic motion.

Introduction

Low back pain (LBP) is the most common neuro-musculoskeletal impairment in golfers. Epidemic evidence suggests that as many as 26–52% reported sports injuries in golfers accounts for LBP (Gluck, Bendo, and Spivak 2008; Gosheger et al. 2003). Such neuro-musculokeletal impairment has been primarily attributed to limited hip joint mobility and muscle imbalance associated with motor recruitment amplitude or strength and viscoelastic extensibility (Ashmen, Buz Swanik, and Lephart 1996; Grimshaw, and Burden 2000; Murray et al. 2009; Vad et al. 2004). Biomechanically, golfers with limited hip rotation was often implicated with LBP suggesting that relative stiffness between hip and lumbopelvic complex may have been compromised due to hip joint constraint (Murray et al. 2009; Vad et al. 2004). This in turn leads to lumbopelvic dyscoordination during golf swing movement. Vad et al. (2004) reported that golfers with history of LBP demonstrated a significant limitation of lead side hip internal rotation as well as lumbar extension than the golfers without LBP. As the body pivots onto the lead leg during swing, decreased amount of hip rotation might cause an increased force to be transmitted to the lumbar spine resulting in LBP.

Individuals with asymmetric hip rotation (internal rotation vs. external rotation) have hip muscle weakness and imbalance (Cibulka et al. 2010; Vad et al. 2004). Janda first coined the term, muscle imbalance characterizing relative inhibition of gluteus maximus (Gmax) and facilitation or overactivation of hip flexors, erector spinae and tensor fascia latae (Janda 1978; Page 2009; Schultz, Andersson, and Haderspeck 1982). This muscle imbalance can result in lumbopelvic instability, which is important prerequisite for

dynamic golf swing movement. For example, Johnson (1999) suggested muscle imbalance may result improper force transmission or redistribution up toward to ipsilateral or contralateral lumbopelvic-hip regions, potentially predispose them at a greater risk for the development of LBP. Sell et al. (2007) demonstrated that higher performing golfers (handicap index < 0) showed significantly greater hip and trunk muscle strength and balance control than lower performing golfers (handicap index 10-20).

Another important biomechanical constraint in the lumbopelvic-hip system (LPHS) contributing to LBP is related with limited extensibility (Sell et al. 2007). For example, decreased iliopsoas muscle length was identified in LBP patients with lumbar lordosis (Ashmen, Buz Swanik, and Lephart 1996; Mellin 1988) whereas decreased hamstring flexibility was also evident in LBP patients with lumbar kyphosis (Ashmen, Buz Swanik, and Lephart 1996; Mellin 1988; Van Wingerden et al. 1997). Recently, another study showed that low handicap golfers had significantly greater hamstring and hip flexors extensibility and hip joint range of motion than high handicaps golfers (Sell et al. 2007). Such limited hip motion due to muscle stiffness may have increased a compensatory hypermobility in the lumbar spinal segments where the least resistance or stiffness is found, susceptible to LBP (Harris-Hayes, Sahrman, and Van 2009).

While different contributing factors have been accounted for LBP in golfers, limited kinematic hip joint motion is an important biomarker of the LBP pathomechanics. Limited hip rotation motion resulting from muscle imbalance might contribute to a compensatory movement in the lumbopelvic region; such compensation could result in

more lumbopelvic movement during rotation related sports, and increasing LBP. Recently, Pollard and Luo (2007) have suggested that one constraint kinetic chain (i.e., hip) can affect other weakest kinetic chain (i.e., lumbar spine) during the golf swing phase, thereby leading to LBP injury (Lindsay, and Horton 2002; McHardy, Pollard, and Luo 2007). The link between incidence of LBP and reduced lead leg hip rotation has been demonstrated amongst professional golfers (Vad et al. 2004). However, underlying mechanisms were not fully understood.

Despite the important clinical ramification, only two studies have examined the effects of the hip rotation on LBP in golfers (Murray et al. 2009; Vad et al. 2004) and revealed significant range of motion (ROM) deficits in the lead hip internal rotation and lumbar spine extension motion in the golfers with a history of LBP (Murray et al. 2009). However, the exact nature of neuromechanical characteristics underpinning the relationship between hip joint movement constraints and LBP pathology are unknown. This present study was to investigate neuromechanical effects on the kinematic lumbopelvic movement patterns in professional golfers with limited hip internal rotation.

Purpose of Study

This purpose of study is to examine kinematics of the lumbar spine, pelvis and hip in pro-golfers with and without limited hip internal rotation and associated muscle imbalance in trunk flexor/extensor and hip joint rotators.

Definitions

Kinematics is defined as a quantitative description of motion in bodies without regard to the forces that cause the motion in a three-dimensional spatial system (An and Chao 1984). Kinematics variables include the position vectors, linear velocity, acceleration, angular displacement, angular velocity, and angular acceleration of the body segment by using motion-capture system (Robertson et al. 2004).

Angular displacement is defined as an angle which calculate changes in angular position (Robertson et al. 2004). In the present study, Pelvic angular displacement was calculated as the angle of pelvis segment with respect to global coordinate system (GLS). Lumbar rotation angle was calculated as the angle of the lumbar segment (L1 spinal level marker to the marker at sacral level) with respect to the pelvic in the anatomical plane. Hip angular displacement was calculated as the angle of the thigh segment with respect to the pelvic in the anatomical plane.

Muscle imbalance is defined as an agonist and an antagonist differences in muscle length or strength; this imbalance occur as a result of adaption or dysfunction (Janda 1978; Sahrmann 2002). In the present study, the trunk and hip rotator strengths were measure to examine muscle imbalance. The strength ratio (agonist and an antagonist) larger differences indicate the greater muscle imbalance.

Limited hip rotation motion is defined as a loss of rotation at the hip joint range of motion (ROM); On average, internal rotation normally ranges from 30 to 40 degrees (approximately 35°), external rotation normally ranges from 40 to 60 degrees (approximately 45°) in prone position (Neumann 2002). Operationally, it is defined as the

hip internal rotation ranges less 20 degrees and normal hip medial rotation angle is more 30 degrees.

Abbreviations

A list of common abbreviation is provided in Table 1.

Table 1. Abbreviations

Abbreviation	Definition
NHIM	Normal left (lead) hip internal motion
LHIM	Limited left (lead) hip internal motion
LBP	Low back pain
CLBP	Chronic low back pain
ROM	Range of motion
SLR	Straight leg raise
Gmax	Gluteus maximus
Gmed	Gluteus medius
BF	Biceps femoris
IR	Internal rotation
ER	External rotation

Research Hypothesis

Primary hypotheses were derived from a review of the literature:

- I. There would be differences in hip, pelvic and lumbar spine kinematics between the group with normal left hip internal motion (NHIM) and the group with limited left hip internal motion (LHIM) during golf swing.
- II. There is significant difference in hip rotator strength and trunk flexor/extensor strengths between two groups.
- III. There is significant difference in iliopsoas and hamstring flexibility between two groups.

Methods

1. Experimental Study Design

Cross-sectional, comparative experimental design

2. Participants

A convenience sample of thirty male professional golfers participated in this study. Subject recruitment was made via online newsletter in the Korea Professional Golfers Association (KPGA) website from December 2011 to March 2012. All participants signed informed consents prior to the participation of this study. Yonsei University Human Ethics and Institutional Review Board (IRB) approved this study. Initially, a total of 34 participants were recruited, but 4 participants were excluded because they did not meet inclusion criteria (hip internal rotation motion was in between 20° and 29°). Clinical measurement including ROM, MMT, Thomas test and SLR were implemented. Faber test was performed to evaluate pathology of the hip joint.

Of the 30 participants, 15 participants demonstrating limited hip internal rotation (<20°) were classified as the experimental group with limited left hip internal motion (LHIM). The other 15 participants demonstrating normal hip internal rotation motion (>30°) were classified as the control group with normal left hip internal motion (NHIM). All participants were right-handed and hand dominance was determined by asking which hand was used to throw a ball. Both groups showed similar demographic and anthropometrical characteristics ($p \geq 0.05$). Participant's demographic and clinical

characteristic data are presented in Table 3.

2.1 Inclusion/Exclusion Criteria

Inclusion criteria entailed certified professional golfers by Korean Professional Golf Association (KPGA) who played at least 9 years. Exclusion criteria included current neurological or musculoskeletal system impairments that affect experimental tests. Clinical measurements were used to determine if they met exclusion criteria.

2.2 Clinical Measurements

Clinical measurements included hip rotation range of motion, FABER test

2.2.1 Hip Joint Internal and Lateral Rotation Motion

The primary assessment was hip joint rotation range of motion using a digital goniometer. The subject lied prone on measurement table. The measure to the hip joint the pelvis was stabilized with a hand of examiner at the level of the posterior inferior iliac spines. The tested hip was placed in knee flexed to 90°, 0° of the hip abduction and opposite hip was abducted to 30° (Cibulka et al. 1998; Ellison, Rose, and Sahrmann 1990). A digital goniometer was positioned proximal to ankle. The leg was the passively moved to produce internal and lateral rotation with the range of motion (ROM) being recorded to the nearest degree at the point of resistance. Final passive range of motion (PROM) was decided when resistance was met or compensatory movement at the pelvis became evident. Three measurements were taken for each trail and a mean was obtained (Vad et al. 2004)

2.2.2 FABER Test

The participants lied supine on the exam table and place the foot on the contralateral knee. And then examiner was press down gently but firmly on the flexed knee and the opposite anterior iliac crest (Magee 2008).

3. Setting

Participants were instructed to wear shorts, tight shirt and golf shoes for all assessments (Chu, Sell, and Lephart 2010; Lephart et al. 2010). All testing procedure took place at the Biomechanics research Laboratory at the Korea Orthopedics & Rehabilitation Engineering Center.

4. Variables

The independent variable included the group factor (LHIM vs. NHIM), which was based on the entering hip internal rotation limitation of the lead leg. The dependent variables included trunk, pelvis and hip kinematics during golf swing, hip rotator and trunk muscles strengths and iliopsoas and hamstring flexibility.

5. Experimental Instruments

5.1 Motion Analysis System

Three-dimensional motion analysis (Motion Analysis Corporation, Santa Rosa, CA) was performed with the use of 8 infrared cameras (120Hz) to determine lumbar spine, pelvis, and hip joint angular kinematics during golf swing (Figure 1). As illustrated in Figure 2, the Helen Hayes full-body marker sets were utilized with twenty-nine 12.5mm reflective markers, which were attached bilaterally to the following anatomic landmarks: heel cord, second metatarsal head, lateral and medial malleoli, tibia tuberosity, lateral and medial femoral epicondyles, anterior superior iliac spine, sacrum, acromion, lateral humeral epicondyle, proximal and distal radioulnar joints, front head, rear head, top of head, and inferior angle of the scapula. Additionally, to define the lumbar segment, 2 markers were secured with athletic tape to the first lumbar spinous process and the right rib of the spinous process at the T12–L1 level (Alter 2004; Sung, Yoon, and Lee 2010; Tsai 2005). One marker also was placed on the golf club to identify the phases of the golf swing, and reflective tape was attached to the ball to define the velocity of the ball.

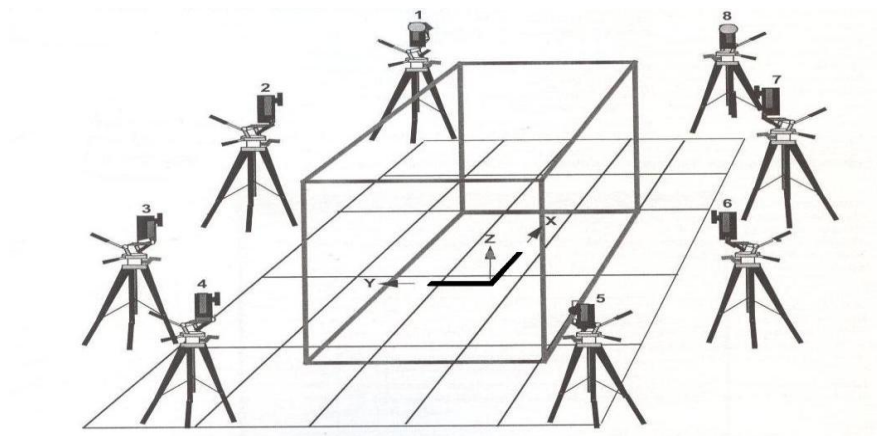


Figure 1. Mimetic diagram of motion analysis system
(Motion Analysis Corp, Santa Rosa, USA)

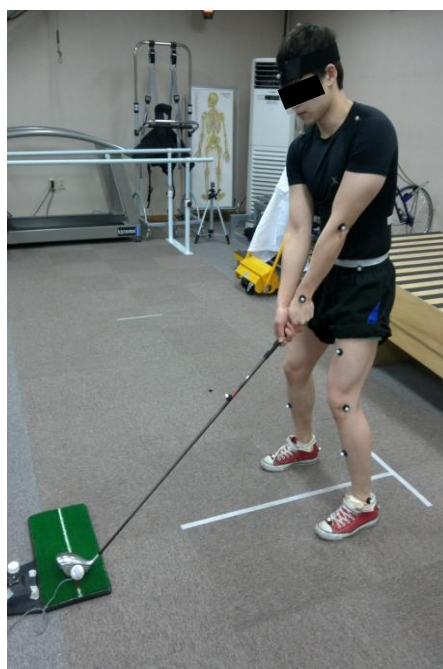


Figure 2. Three-dimensional biomechanical analysis of the golf swing

5.2 Digital Goniometer

Hip rotation was measured with a digital goniometer (digital display goniometer SP-II; Jiangmen) and elasticity bands (Figure 3). Three tests were conducted for each rotation, and rotation was defined as the average measurements obtained for both the hips.



Figure 3. Digital goniometer (digital display goniometer SP-II, Jiangmen)

5.3 Biodex and Handheld Dynamometer

Trunk muscle strength was evaluated by using the Biodex System III (Biodex Medical Systems Inc., Shirley, NY) (Figure 4). Isometric hip rotators strengths were measured by using a handheld dynamometer (PowerTrack II Commander; JTECH Medical, Salt Lake City, UT) (Figure 5).



Figure 4. Biodex system III (Biodex Medical Inc, Shirley, NY)



Figure 5. Handheld dynamometer

(PowerTrack II Commander, JTECH Medical, Saltlake City, Utah)

6. Procedures

All subjects participated in 2 testing sessions: First, subjects underwent motion evaluation while performing a golf swing. After the golf swing, we evaluated the trunk and hip muscle strength and hamstring and iliopsoas flexibility of the subjects. This procedure was performed to prevent any possible influence of fatigue on the biomechanical evaluation.

6.1. Motion Analysis

Before the commencement of data collection, each participant was instructed to perform his typical warm-up. Then, a static calibration trial was collected for each subject prior to measurement. Subjects were instructed to stand in an anatomic position with their feet. Subjects hit a golf ball with their driver club to better replicate their actual swing pattern while playing. The subjects stood with 1 foot on each force plate and hit 10 shots off an artificial golf mat and into a curtain. Of the 10 shots, 5 shots with the highest ball velocity were analyzed and averaged (Lephart et al. 2010). Select kinematic variables were calculated at 6 critical events of the golf swing: address, top of backswing, acceleration (downswing), impact, follow through, and finish (Table 2, Figure 6).

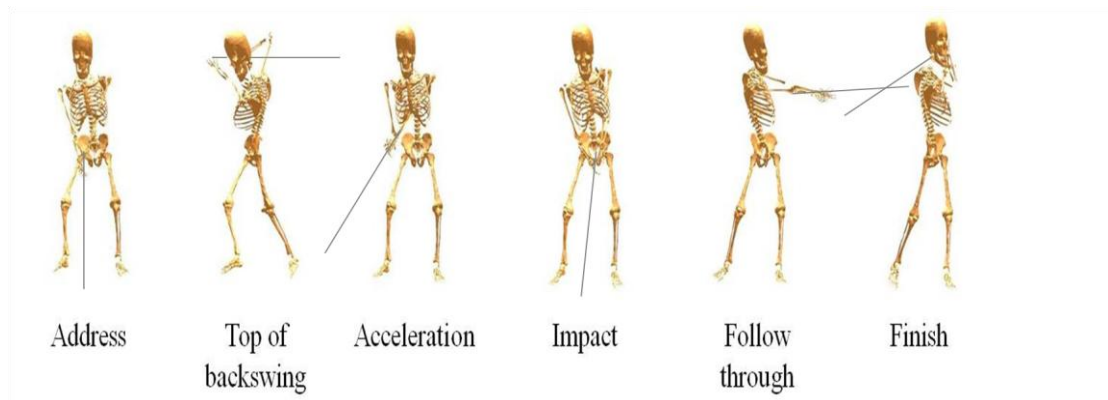


Figure 6. Six critical events of the golf swing

Table 2. Description of 6 analyzed swing points

Phases	Description
Address	Point where club begins to move
Top of backswing	Point where club begins to be pulled down
Acceleration	The time between the top of the backswing and impact 66% point of between top of backswing and impact (Chu, Sell, and Lephart 2010).
Impact	Point where club head contacts the ball
Follow-through	The time between the impact and finish
Finish	Point where the club head stops the swing

6.2 Flexibility Test

Hip joint extensibility was determined by measuring muscle length based on the following special tests.

Hamstring flexibility was measured by using a digital goniometer during the passive straight leg raise (SLR) test. Participants were positioned supine on a table, with a firm lumbar support. The pelvis was stabilized with a belt, and the opposite leg was fixed on the table by the examiner's hand. The examiner then passively extended the knee by regular force, and the knee's angle was measured with the digital goniometer. A total of 3 trials were conducted (Arab, Nourbakhsh, and Mohammadifar 2011).

Iliopsoas contracture was evaluated using the Thomas test. The subjects were placed in the supine position on the examination table, with their knees bent over the edge. They were instructed to flex one knee to the chest and hold it. At the same time, the examiner measured the angle between the tested thigh (opposite of the knee held to the chest) and the table (Schultz, Andersson, and Haderspeck 1982).

6.3 Strength Test of Trunk Muscles and Hip Rotators

Trunk muscle strength was measured by using the Biodex System III. Isokinetic strength of trunk flexion and extension was evaluated with the participants in a seated position. Subjects performed 5 repetitions at 60°/second during trunk flexion and extension. A total of 5 trials were conducted, with a 1-minute resting period between each trial (Lephart et al. 2010).

Hip rotators strength was tested by a handheld dynamometer (Roberts 2003). Subjects were seated in a Biodex chair and stabilized with multiple straps and a hip abduction wedge. Their hips and knees were flexed at 90°, and their hips were in neutral position. For assessing the lateral hip rotators, the dynamometer was applied just proximal to the malleolus. The subjects were asked to keep their arms held against the body, and their hips were positioned in a slight lateral rotation, with the medial malleolus aligned with the midline of the body. The medial rotators were evaluated with the hips in a neutral rotation, with resistance to movement applied just above the lateral malleolus. The duration of each maximal isometric contraction was standardized at 5 seconds. Three trials were performed, with a resting period of 30 seconds between each trial.

7. Data Analysis

The measured kinematic data were analyzed using biomechanical analysis software (Cortex 1.3, Motion Analysis Corporation, Santa Rosa, CA). The kinematic data of the 5 highest ball velocities for each subject were analyzed and averaged.

The body segments were modeled as rigid bodies, and the relative angle was taken from a fixed point in the center of the joint. The lumbar segment angle was calculated on the second sacrum and first lumbar vertebrae spinous process. The segment's axis was calculated by the method proposed by Sung et al. (2010).

Trunk torque data were transferred from the Biodex System workstation to a personal computer. Peak torque values of strength were identified in each trial and normalized to body mass. Trunk torque, hip rotator force and SLR data were imported into Excel (Microsoft Corporation, Redmond, WA). For all variables, the average of 3 trials was used for statistical analysis.

8. Statistical Analysis

The descriptive statistics include the means and standard deviations. The results were analyzed using SPSS version 17.0 software (IBM Corporation, Armonk, NY). A two-tailed independent t-test and the one-sample Kolmogorov–Smirnov test were conducted to verify the differences in the general characteristics of the groups, and to test the normality of the distribution, respectively. The Thomas test values did not demonstrate a normal distribution; therefore, the Mann–Whitney U test was conducted to compare the differences in the Thomas test values between the 2 groups. Pearson's correlation test was used to analyze the correlation between maximum left rotation of the pelvis and passive range of motion of the hip. Statistical significance was defined as $p < 0.05$.

Results

1. Demographic and Anthropometric Data

Table 3 presents the demographic and anthropometric data of participants.

Table 3. Demographic and anthropometrical characteristics of participants (N=30)

	LHIM group (n=15)	NHIM group (n=15)	p
Age (years)	29.0±4.9 ^a	31.0±4.5	.135
Height (cm)	178.1±6.1	178.6±9.3	.424
Mass (kg)	78.8±12.6	76.6±14.6	.331
Golf career (years)	13.3±2.4	12.3±2.3	.369
Right hip IR ROM (degree)	28.6±2.1	29.7±3.2	.172
Right hip ER ROM (degree)	40.1±8.8	41.6±7.0	.301
Left hip IR ROM (degree)	17.2±5.0	33.1±2.9	.000 [*]
Left hip ER ROM (degree)	51.3±8.2	40.0±5.4	.000 [*]
Maximum golf ball velocity (cm/s)	438.8±63.8	423.9±58.7	.276

Abbreviations: IR, internal rotation; ER, external rotation; ROM, range of motion.

^a Data are mean ± SD.

^{*} p < 0.05

2. Clinical Data

2.1 Muscle Length Test Data

2.1.1 Passive SLR Test Data

Independent t-test showed that LHIM group demonstrated significantly less knee extension in the right leg than NHIM group (mean \pm SD, 13.06 ± 5.29 versus 5.73 ± 2.65 ; t value=4.792, p=0.000). No statistically significant difference was observed in the left leg (mean \pm SD, 9.60 ± 5.26 versus 9.41 ± 5.08 ; t value=0.271, p=0.789) (Figure 7). These results indicate that shortness in hamstring muscles were evident between the groups.

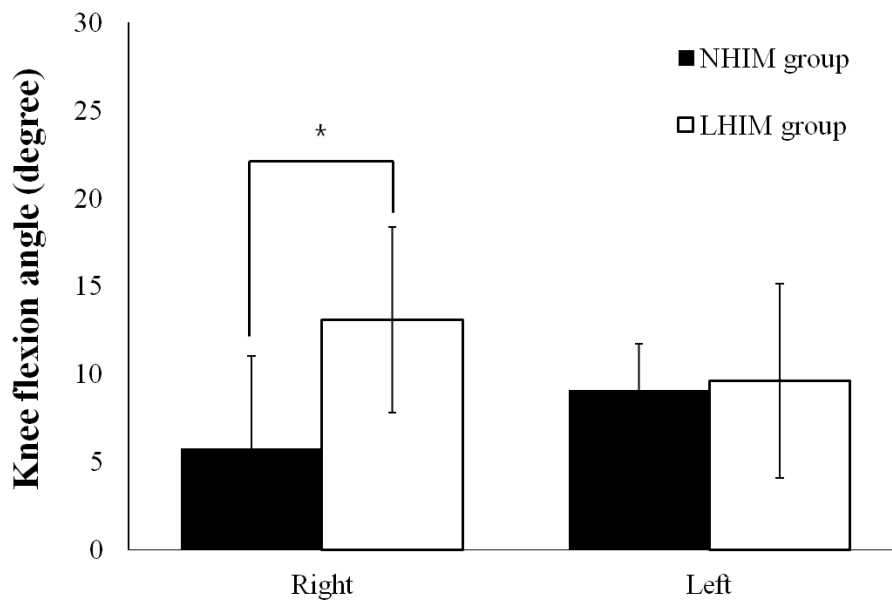


Figure 7. Comparison of knee flexion angle between 2 groups

* p < 0.05

2.1.2 Thomas Test Data

The Mann-Whitney test revealed more increased hip flexion angle in the LHIM group than in the NHIM group (mean \pm SD, 21.8 ± 10.11 versus 9.53 ± 10.94 ; z value=-2.221, p=0.017). No significant difference was observed in the left leg between groups (mean \pm SD, 14.67 ± 12.82 versus 15.00 ± 14.01 ; z value=-0.063, p=0.471) (Figure 8). These results indicate that shortness in iliopsoas muscles were evident between the groups.

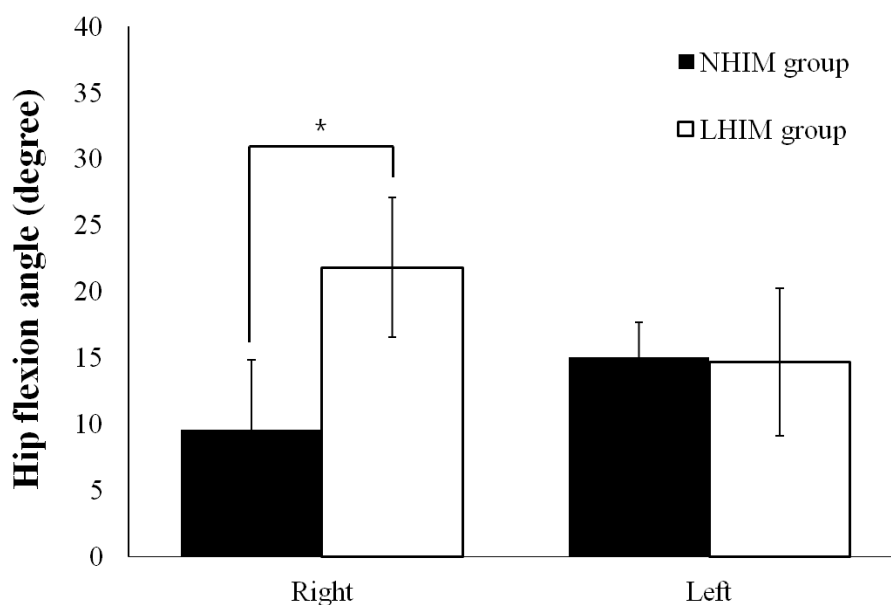


Figure 8. Comparison of hip flexion angle between 2 groups

* p < 0.05

2.2 Muscle Strength Test Data

2.2.1 Trunk Flexor and Extensor Strength Data

Independent t-test showed no statistically significant difference in both trunk flexion ($p=0.139$) and extension strengths ($p=0.634$) (Table 4). The extensor/flexor strength ratio was 1.53:1 and 1.32:1 in the LHIM group and NHIM group, respectively.

Table 4. Isokinetic strength for trunk muscles

Muscles	LHIM group	NHIM group	t-value
Extensor (%BW)	178.76±79.74 ^a	193.31±85.31	0.482
Flexor (%BW)	114.64±47.81	142.27±51.59	1.521

Abbreviations: %BW, percent body weight (peak torque [Nm]/body weight [kg] X100)

^a Data are mean ± SD.

* $p < 0.05$

2.2.2. Hip Rotator Strength Data

Independent t-test showed more decreased right hip external rotator strength ($p=0.024$) and left hip internal rotator strength ($p=0.001$) in the LHIM group than in the NHIM group (Table 5).

The hip rotator strength ratio between groups is shown in Table 5. Independent t-test revealed that left and right hips rotator strength ratio was significantly different between 2 groups. Strength ratio closer to 1 means a symmetrical condition; these results indicate that muscle strength imbalance between the IR and ER muscles were evident between the groups.

Table 5. Isometric hip rotators strength and ratio between group comparisons

Hip rotators	LHIM group	NHIM group	t-value
External rotator (N/kg)			
Right limb	0.94±0.14 ^a	1.09±0.20	2.371 [*]
Left limb	1.14±0.19	1.18±0.15	0.502
Internal rotator (N/kg)			
Right limb	1.22±0.16	1.22±0.12	0.141
Left limb	1.01±0.13	1.23±0.18	3.832 [*]
Ratio			
Rt. ratio (ER/IR)	0.77±0.17	0.89±0.12	-2.497 [*]
Lt. ratio (ER/IR)	1.12±0.16	0.96±0.16	-4.351 [*]

Abbreviations: ER, external rotator; IR, internal rotator

^a Data are mean ± SD.

^{*} p < 0.05

3. Kinematic Parameters

3.1 Lumbar Kinematics

Independent t-test showed that the lumbar rotation was significantly increased more in the LHIM group than in the NHIM group at the top of backswing phase ($p=0.000$), follow-through phase ($p=0.012$) and finish phase ($p=0.020$) of the golf swing cycle (Table 6, Figure 9). The lumbar right side bending was also significantly increased more in the LHIM group than in the NHIM group at the impact phase ($p=0.016$) and finish phase ($p=0.003$). The LHIM group showed significantly increased lumbar flexion angles as compared to the NHIM group ($p=0.000$) in address, top of backswing, acceleration and impact phases (Table 6, Figure 9). These findings suggest that the restricted hip internal rotation may contribute to excessive lumbar motion.

Table 6. Comparison of lumbar motion angle between two groups in each phase

Phase	Plane	LHIM group	NHIM group	t-value	p
Address	Sagittal	11.07±1.34 ^a	5.64±3.03	6.328*	.000
	Coronal	-2.93±0.69	-3.11±0.41	0.853	.401
	Transverse	5.31±0.99	8.65±2.88	-4.242*	.000
Top of backswing	Sagittal	13.95±1.10	7.61±1.67	12.250*	.000
	Coronal	5.37±0.83	5.34±2.84	0.041	.968
	Transverse	-12.91±2.17	-6.45±2.88	-6.931*	.000
Acceleration	Sagittal	12.65±1.11	8.70±1.31	8.864*	.000
	Coronal	2.32±1.16	4.89±2.87	-3.202*	.003
	Transverse	-4.20±3.30	-1.89±4.29	-1.647	.111
Impact	Sagittal	5.88±1.31	1.73±0.11	10.459*	.000
	Coronal	-6.77±2.74	-4.18±2.77	-2.570*	.016
	Transverse	3.58±2.69	5.70±2.30	-2.309*	.029
Follow through	Sagittal	-1.15±1.23	-1.36±1.81	0.381	.706
	Coronal	-22.40±2.12	-20.28±4.19	-1.746	.092
	Transverse	22.33±2.49	20.27±1.58	2.697*	.012
Finish	Sagittal	-1.56±1.54	-1.05±1.40	-0.947	.502
	Coronal	-21.89±1.97	-18.78±3.07	-3.296*	.003
	Transverse	16.04±2.85	13.66±2.41	2.469*	.020

^a Data are mean ± SD

* p < 0.05

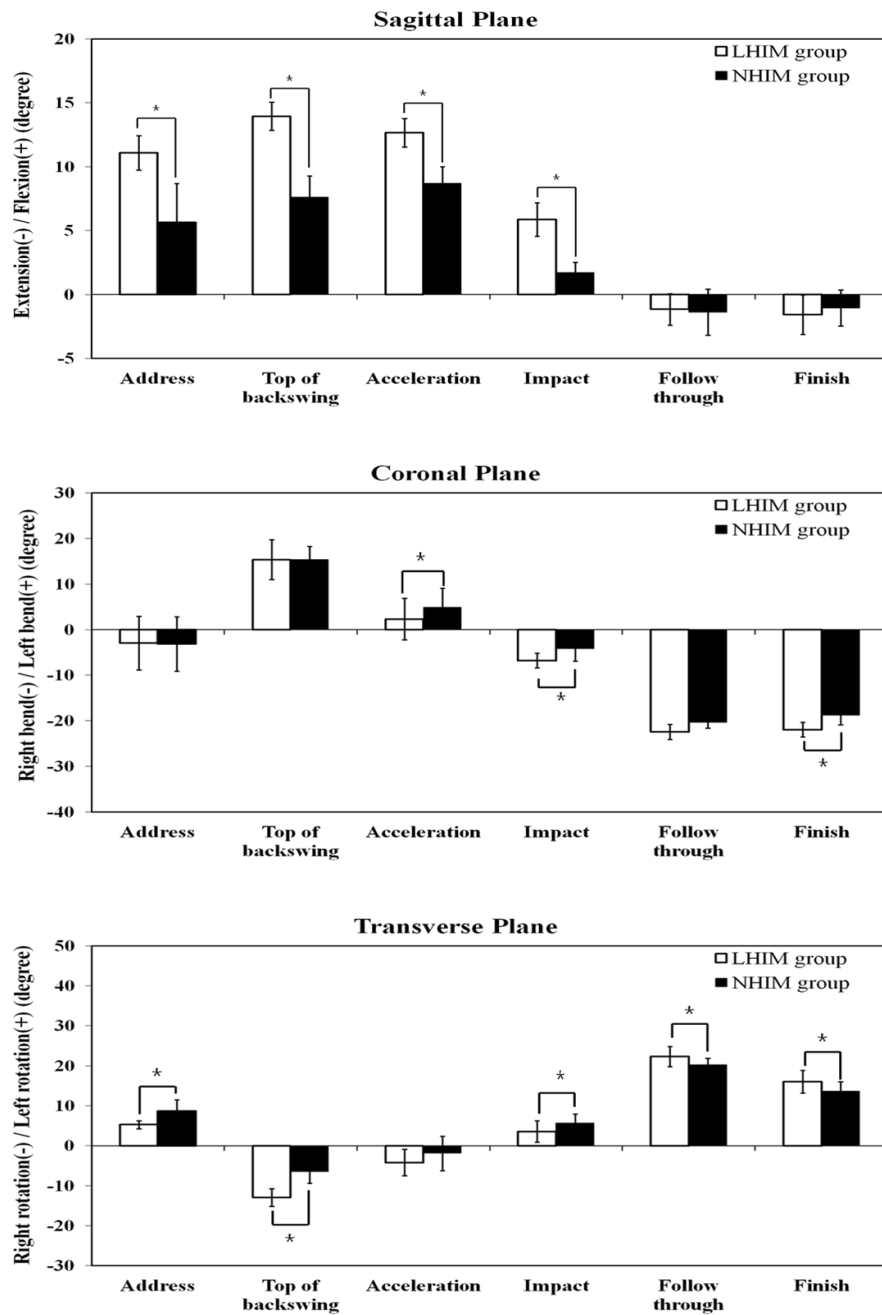


Figure 9. Comparison of lumbar motion angle between two groups in each phase

* $p < 0.05$

3.2 Pelvis Kinematics

Independent t-test showed that the pelvis rotation was significantly decreased more in the LHIM group than in the NHIM group ($p=0.000$) at the follow-through phase and finish phase of the golf swing cycle (Table 7, Figure 10). These findings suggest that the restricted hip internal rotation may result in limited pelvic motion.

The pelvis anterior tilt was significantly decreased more in the LHIM group than in the NHIM group at the acceleration phase ($p=0.021$); however, in the top of backswing phase, the pelvis anterior tilt was increased more in the LHIM group than in the NHIM group ($p=0.041$).

Table 7. Comparison of pelvis motion angle between two groups in each phase

Phase	Plane	LHIM group	NHIM group	t-value	p
Address	Sagittal	22.25±5.83 ^a	19.30±6.00	1.368	.182
	Coronal	-1.85±3.23	-0.34±2.25	-1.488	.149
	Transverse	1.95±3.62	1.61±3.50	0.261	.796
Top of backswing	Sagittal	18.00±4.35	15.08±2.94	2.155*	.041
	Coronal	-1.41±5.32	-4.99±3.64	2.150*	.042
	Transverse	-58.84±4.68	-57.19±5.46	-0.886	.383
Acceleration	Sagittal	7.75±4.52	10.65±4.17	-2.456*	.021
	Coronal	5.93±3.61	4.90±1.84	3.841*	.001
	Transverse	1.79±0.86	1.43±1.28	0.909	.373
Impact	Sagittal	5.20±1.61	7.91±2.64	0.522	.606
	Coronal	-6.95±1.28	-8.13±1.13	1.177	.249
	Transverse	33.41±4.91	35.51±7.23	0.606	.549
Follow through	Sagittal	7.61±1.66	6.95±1.25	1.226	.231
	Coronal	0.16±0.21	-0.34±1.75	-0.238	.811
	Transverse	92.17±3.40	107.28±7.26	-7.301*	.000
Finish	Sagittal	6.89±1.62	5.92±2.03	1.435	.163
	Coronal	2.48±1.85	1.26±1.29	0.853	.401
	Transverse	95.22±3.42	110.71±7.64	-7.160*	.000

^a Data are mean ± SD

* p < 0.05

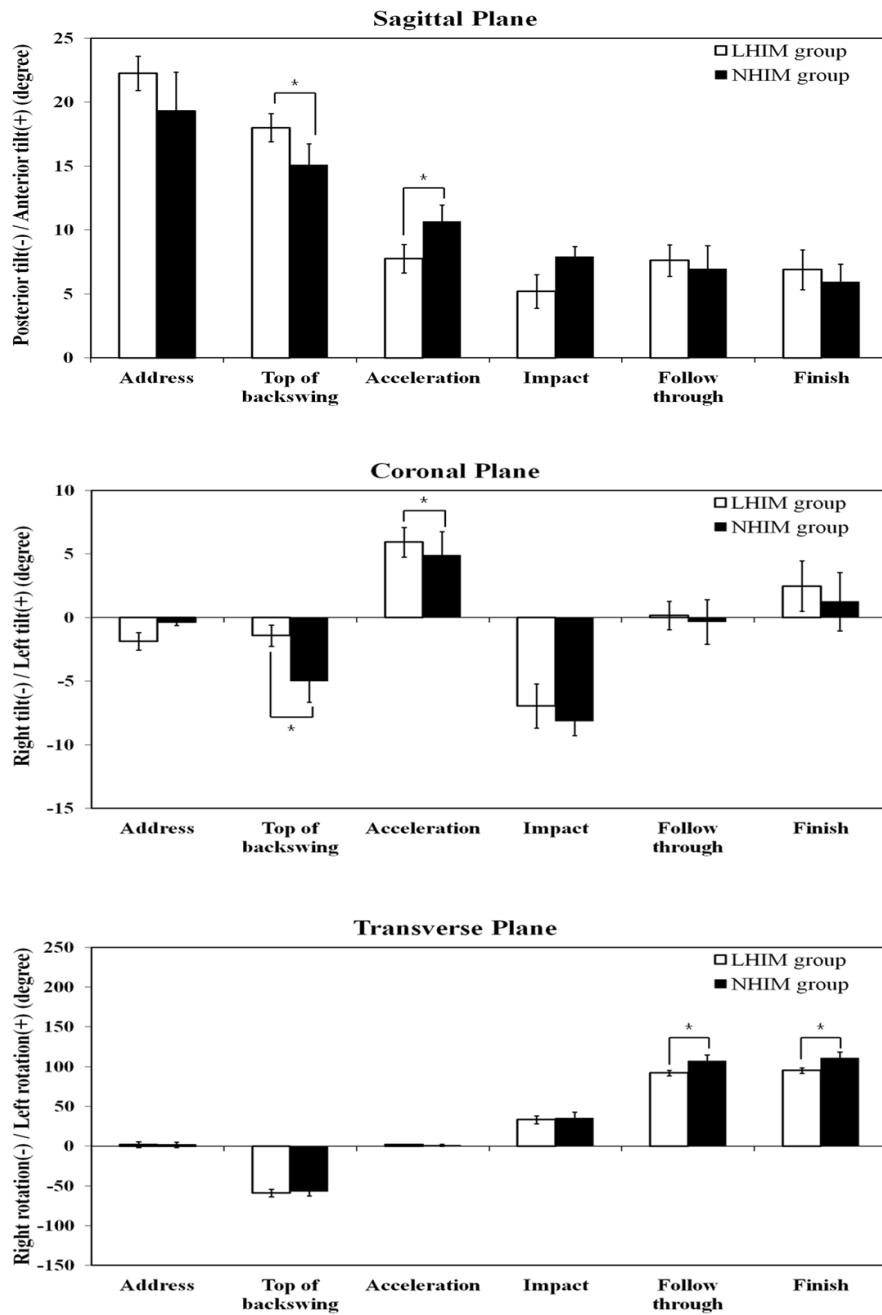


Figure 10. Comparison of pelvis motion angle between two groups in each phase

* $p < 0.05$

3.3 Hip Kinematics

Independent t-test showed that the LHIM group had significantly less left hip internal rotation angle than NHIM group at the finish phase (mean \pm SD, 10.87 ± 4.50 versus 18.73 ± 8.45 ; t value= -3.175, p=0.004) (Figure 11).

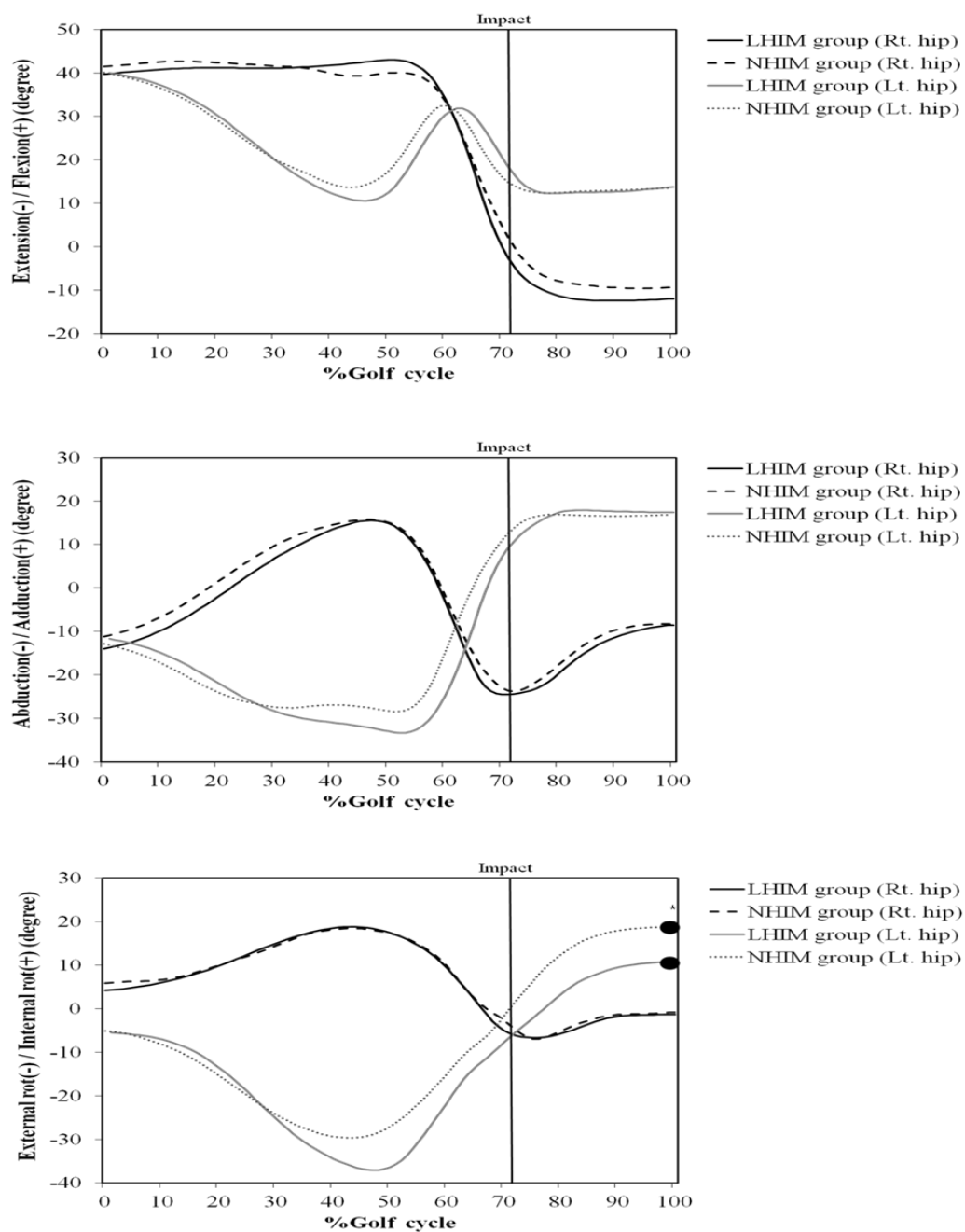


Figure 11. Comparison of hip motion angle between two groups during golf swing

Abbreviations: Rt, right; Lt, left; rot, rotation. * $p < 0.05$

3.4 Correlation Analysis

Pearson's correlation test revealed a positive relationship between left hip IR PROM and left pelvic rotation during golf swing ($r=0.603$, $p=0.000$). However, left hip ER PROM was negatively correlated with left pelvic rotation ($r= -0.441$) (Table 8).

Table 8. Pearson's correlation analysis in all subjects

PROM	Maximum left rotation of pelvis	
	r	p
Trail side of hip		
External rotation	0.23	.223
Internal rotation	0.33	.071
Lead side of hip		
External rotation	-0.44*	.016
Internal rotation	0.60*	.000

* $p < 0.05$

Discussion

This present study highlighted important neuromechanical characteristics in the lumbo-pelvis-hip in professional golfers with limited hip internal rotation during golf swing. As anticipated, we found that golfers with limited hip rotation constraints showed greater lumbar rotation movement than controls. Moreover, such limited hip rotation was associated with hip muscle strength imbalance (internal vs. external rotators) and hamstring and iliopsoas extensibility. Certainly, our novel findings suggest that limited hip internal rotation resulting from muscle imbalance may have contributed excessive lumbar rotation movement and altered coordinated lumbopelvic-hip movement control during golf swing, thereby potentially leading to a higher risk of lumbar pathology in professional golfers. However, to the best of our knowledge, no neuromechanical evidence validating the influence of the limited hip rotation on lumbopelvic movement is currently available, which makes it practically difficult to compare our novel findings with previous studies.

Most importantly, our biomechanical analysis of lumbopelvic movement demonstrated a substantially larger axial lumbar rotation angle and lesser pelvis rotation angle in the pro-golfers with limited hip internal rotation of the lead leg than normal controls. Specifically, at both the top of back swing and after-impact phases, lumbar rotation was markedly increased in pro-golfers with limited hip motion than controls. Similarly, during the down swing phase, lumbar flexion and pelvic posterior rotation were evident while from the impact phase to the finish phase, lateral bending was significantly

increased. In normal golf biomechanics, the greater the spinal rotation at the top of backswing is desirable since it can generate greater force from a tightly recoiled spring-mass model which stored up potential energy to be used as kinetic energy as it is quickly released during the downswing phase; subsequently, leading to maximum club head speed at impact (Geisler 2001). Finish the golf swing with extension, lateral bending, and rotation of trunk allows the golfer to efficiently absorb the released energy during the downswing (Myers et al. 2008). However, in the present study, such normal kinetic link between lumbopelvic-hip chains may have been compromised in golfers with limited hip internal rotation, and hence they may have to increase axial lumbar rotation to compensate the altered kinetic chain (Harris-Hayes, Sahrman, and Van 2009). Overtime, repetitive and excessive lumbar spinal rotation along with flexion and lateral bending may increase lumbar segmental mobility (hypermobility), which can weaken the kinetic link within the lumbopelvic-hip chain system. This lumbar segmental hypermobility in the weakened lumbopelvic-hip kinetic chain will impose shearing and compression loads on the lumbar spine and intervertebral joints, resulting in mechanical low back pain associated with facet arthropathy and herniated disc (Lindsay, and Horton 2002; Sugaya et al. 1999).

The 2 groups produced similar ball velocity, but lumbar flexion motion (from address to impact phase) and right-side bending motion (after impact phase) occurred to a greater extent in golfers with limited hip internal rotation of the lead leg than in controls. Importantly, increased flexion is associated with increased lumbar disc pressure and LBP (Kumar, Narayan, and Zedka 1998). Most stress and injuries occur during downswing

(Sugaya et al. 1999). Therefore, increased lumbar flexion motion during downswing could contribute to LBP. Furthermore, right bending—a risk factor for LBP—occurs throughout the golf swing, except at the top of the backswing. Increased lateral bending on the trailing side may lead to spinal injury. Sugaya et al. (1999) found that 55% of Japanese tour pro-golfers had LBP, of which over 50% had localized pain in the trailing side. Radiographic analysis revealed significantly greater vertebral body and facet joint arthritis in the trailing side as compared to healthy golfers.

The maximum left pelvis rotation (at finish phase) of pro-golfers is approximately 100–120° (David 2011); consistent with the present results. Golfers with limited hip internal rotation of the lead leg showed smaller left pelvis rotation angle than healthy controls, consistent with limited lead hip internal rotation. Correlation analysis of the maximum pelvis left rotation angle during golf swing and the passive internal ROM of the lead hip revealed that they were weakly positively correlated when the passive internal ROM of the hip decreased and the maximum pelvis left rotation angle decreased ($r = 0.603$). This means that after impact, the pelvis left rotation angle was decreased according to hip joint constraint of the lead leg. Montgomery (2011) reported that stiffening of the lower body may occur, decreasing the ability of the pelvis to rotate over the legs. Excessive or restrictive rotation in one area of the body may lead to increased load on other body parts (Montgomery, Boocock, and Hing 2011). Therefore, limited hip internal rotation of the lead leg may lead to restrictive left rotation of the pelvis.

Golfers with limited hip internal rotation of the lead leg had significantly shorter right-leg hamstrings ($p = 0.000$) and iliopsoas ($p = 0.017$) than controls. Trunk strength

was similar in the 2 groups. However, golfers with limited hip internal rotation of the lead leg exhibited less strength in the right hip external rotator ($p = 0.024$) and left hip internal rotator ($p = 0.001$) than controls. Gmax, gluteus medius (as rotator), biceps femoris (BF), and hip flexor in the trail leg—which initiates pelvic rotation—show peak activity during early downswing (Bechler et al. 1995); hence, when the right hip external rotator muscles are weak, compensatory overuse of the BF and hip flexor of the trail leg will occur, eventually leading to muscle shortening (Janda 1978; Sahrman 2002). Shortening of the hamstring and iliopsoas in the trail leg influences pelvic tilt (Kendall, McCreary, and Provance 1993; Kolber, and Zepeda 2004; van Wingerden et al. 1997) and lumbar motion (Hansson et al. 1985; Sahrman 2002). Golfers with limited hip internal rotation of the lead leg showed smaller anterior tilt of the pelvis during downswing than controls, possible because of hamstring shortening. The hamstring in the lead leg is mainly activated as an accelerator during downswing (Vijay 2007); however, in the case of muscle shortness, pelvic motion is altered. Tight hamstrings compensate for pelvic instability, resulting in decreased lumbar lordosis by limiting the ability to anterior tilt the pelvis (Kendall, McCreary, and Provance 1993). In addition, decreased lumbar lordosis may alter the nucleus pulposus within the disc, further increasing the risk for LBP (Kolber, and Zepeda 2004). The iliopsoas muscle shortness leads to more lumbar flexion motion and flexion moment on all segments of the lumbar spine upon trunk flexion (Sahrman 2002). During golf swing, the hip flexors in the trail leg are mainly active until the impact phase, with lumbar flexion movement being partly affected by hip flexor activity. Hip muscle strength imbalances and shortness alter the coordination of the hip musculature,

and lumbopelvic region motion is changed, causing mechanical elements to be stressed (Harris-Hayes, Sahrmann, and Van 2009)

The study limitations provide useful directions for further research. First, the each hip muscle strengths and lengths were not measure. The results of this study were insufficient to find the cause in detail. Second, the thoracic segment motion was not measure. The identifying of thoracic segment motion in golfer with LHIM during golf swing would be powerful study for mechanism of pathologic golf swing. Finally, in future studies, excessive lumbar rotation in pro-golfers with LHIM at the top of backswing will be needed investigate through a variety of methods.

Conclusions

This study is the first to empirically confirm the pathomechanics involved in the lumbopelvic movements in professional golfers who show limited internal rotation at the lead hip. The results of this study are as follows:

1. Golfers with LHIM show relative hip muscle weakness (in particular, weakness in the internal rotator muscles in the lead hip and the external rotator muscles in the trail hip) and muscle length shortness (shortness in iliopsoas and hamstring in the trail hip) compared to golfers with NHIM.

2. The ball velocity produced between the golfers of the 2 groups was found to be similar. However, the lumbar-spine movements during golf swing in golfers with LHIM involve greater flexion (from the address phase to the impact phase), right/left rotation (at the top of backswing, follow-through phase, and finish phase), and right side bending (at the impact phase and the finish phase) than those in golfers with NHIM.

3. Golfers with LHIM showed greater posterior tilt of the pelvis during downswing and lesser rotation at the follow-through and finish phases than golfers with NHIM.

Our results suggest that professional golfers with limited hip internal rotation develop muscles strength imbalance and shortness at the hips, which contributes to altered lumbopelvic movements and is a potential risk factor for LBP.

References

- Alter MJ. 2004. *Science of Flexibility*. Human Kinetics.
- An KN, and Chao EY. 1984. "Kinematic analysis of human movement". *Ann Biomed Eng.* 12(6): 585-597.
- Arab AM, Nourbakhsh MR, and Mohammadifar A. 2011. "The relationship between hamstring length and gluteal muscle strength in individuals with sacroiliac joint dysfunction". *J Man Manip Ther.* 19(1): 5-10.
- Ashmen KJ, Buz Swanik C, and Lephart SM. 1996. "Strength and flexibility characteristics of athletes with chronic low-back pain". *J Sport Rehabil.* 5(4): 275-286.
- Bechler JR, Jobe FW, Pink M, Perry J, and Ruwe PA. 1995. "Electromyographic analysis of the hip and knee during the golf swing". *Clin J Sport Med.* 5(3): 162-166.
- Chu Y, Sell TC, and Lephart SM. 2010. "The relationship between biomechanical variables and driving performance during the golf swing". *J Sport Sci.* 28(11): 1251-1259.

Cibulka MT, Sinacore DR, Cromer GS, and Delitto A. 1998. "Unilateral hip rotation range of motion asymmetry in patients with sacroiliac joint regional pain". *Spine*. 23(9): 1009-1015.

Cibulka MT, Strube MJ, Meier D, Selsor M, Wheatley C, Wilson NG, and Irrgang JJ. 2010. "Symmetrical and asymmetrical hip rotation and its relationship to hip rotator muscle strength". *Clin Biomech*. 25(1): 56-62.

D. Gordon E. Robertson, Graham E. Caldwell, Joseph Hamill, Gary Kamen, and Whittlesey SN. 2004. *Research Methods in Biomechanics*. Human Kinetics.

Ellison JB, Rose SJ, and Sahrmann SA. 1990. "Patterns of hip rotation range of motion: A comparison between healthy subjects and patients with low back pain". *Phys Ther*. 70(9): 537-541.

Geisler PR. 2001. *Golf*. New York. McGraw-Hill.185-225.

Gluck GS, Bendo JA, and Spivak JM. 2008. "The lumbar spine and low back pain in golf: A literature review of swing biomechanics and injury prevention". *Spine J*. 8(5): 778-788.

Gosheger G, Liem D, Ludwig K, Greshake O, and Winkelmann W. 2003. "Injuries and overuse syndromes in golf". *Am J Sport Med.* 31(3): 438-443.

Grimshaw PN, and Burden AM. 2000. "Case report: Reduction of low back pain in a professional golfer". *Med Sci Sport Exer.* 32(10):1667-1673.

Hansson T, Bigos S, Beecher P, and Wortley M. 1985. "The lumbar lordosis in acute and chronic low-back pain". *Spine.* 10(2): 154-155.

Harris-Hayes M, Sahrmann SA, and Van Dillen LR. 2009. "Relationship between the hip and low back pain in athletes who participate in rotation-related sports". *J Sport Rehabil.* 18(1): 60-75.

Janda V. 1978. Muscles, Central Nervous Motor Regulation and Back Problems. In: I.M.Korr. *The Neurobiologic Mechanisms in Manipulative Therapy*. New York: Pleum Press.27-41.

Kendall FP, McCreary EK, and Provance PG. 1993. *Muscles: Testing and Function with Posture and Pain*. Forth ed. Williams &Wilkins.

- Kolber MJ, and Zepeda J. 2004. "Addressing hamstring flexibility in athletes with lower back pain: A discussion of commonly prescribed stretching exercises". *Strength Cond J*. 26(1): 18-23.
- Kumar S, Narayan Y, and Zedka M. 1998. "Trunk strength in combined motions of rotation and flexion/extension in normal young adults". *Ergonomics*. 41(6): 835-852.
- Lephart SM, Tsai YS, Sell TC, Smoliga JM, Myers JB, and Learman KE. 2010. "A comparison of physical characteristics and swing mechanics between golfers with and without a history of low back pain". *J Orthop Sports Phys Ther*. 40(7): 430-438.
- Lindsay D, and Horton J. 2002. "Comparison of spine motion in elite golfers with and without low back pain". *J Sport Sci*. 20(8): 599-605.
- Magee DJ. 2008. *Orthopedic Physical Assessment*. 5th ed. SAUNDERS.
- McHardy A, Pollard H, and Luo K. 2007. "One-year follow-up study on golf injuries in australian amateur golfers". *Am J Sport Med*. 35(8): 1354-1360.
- Mellin G. 1998. "Correlations of hip mobility with degree of back pain and lumbar spinal mobility in chronic low-back pain patients". *Spine*. 13(6): 668-670.

Montgomery T, Boocock M, and Hing W. 2011. "The effects of spinal posture and pelvic fixation on trunk rotation range of motion". *Clin Biomech*. 26(7): 707-712.

Murray E, Birley E, Twycross-Lewis R, and Morrissey D. 2009. "The relationship between hip rotation range of movement and low back pain prevalence in amateur golfers: An observational study". *Phys Ther in Sport*. 10(4): 131-135.

Myers J, Lephart S, Tsai YS, Sell T, Smoliga J, and Jolly J. 2008. "The role of upper torso and pelvis rotation in driving performance during the golf swing". *J Sport Sci*. 26(2): 181-188.

Neumann DA. 2002. *Kinesiology of the Musculoskeletal System: Foundations for Physical Rehabilitation*. Mosby. 669.

Page Phil FCC, Lardner, and Robert. 2009. *Assessment and Treatment of Muscle Imbalance*. Human Kinetics Publishers.

Roberts A. 2003. *Statics and Dynamics with Background Mathematics*. Queen's University Belfast.

Sahrmann SA. 2002. *Diagnosis and Treatment of Movement Impairment Syndromes*. Mosby.

- Schultz AB, Andersson GBJ, and Haderspeck K. 1982. "Analysis and measurement of lumbar trunk loads in tasks involving bends and twists". *J Biomech.* 15(9): 669-675.
- Sell TC, Tsai YS, Smoliga JM, Myers JB, and Lephart SM. 2007. "Strength, flexibility, and balance characteristics of highly proficient golfers". *J Strength Cond Res.* 21(4): 1166-1171.
- Sugaya H, Tsuchiya A, Moriya H, Morgan DA, and Banks SA. 1999. "Low back injury in elite and professional golfers: An epidemiologic and radiographic study". *Science and Golf III: Proceedings of the World Scientific Congress of Golf.* 83-91.
- Sung PS, Yoon B, and Lee DC. 2010. "Lumbar spine stability for subjects with and without low back pain during one-leg standing test". *Spine.* 35(16): E753-E760.
- Tsai YS. 2005. *Biomechanical and Physical Characteristics of Trunk and Hip in Golfers with and without Low Back Pain.* Dissertation. Faculty of School of Health and Rehabilitation Sciences, University of Pittsburgh.
- Vad VB, Bhat AL, Basrai D, Gebeh A, Aspergren DD, and Andrews JR. 2004. "Low back pain in professional golfers: The role of associated hip and low back range-of-motion deficits". *Am J Sport Med.* 32(2): 494-497.

van Wingerden JP, Vleeming A, Kleinrensink GJ, and Stoeckart R. 1997. The Role of The Hamstrings in Pelvic and Spinal Function. In: *Movement, Stability and Low Back Pain: The essential role of the pelvis*. Churchill Livingstone, 207-210.

Vijay Vad DA. 2007. *Golf rx: A 15-minute-a-day core program for more yards and less pain*. Gotham.

국문요약

고관절 내회전이 제한된 프로 골퍼의 요골반부 움직임에 대한 병리학

연세대학교 보건환경대학원

인간공학치료학 전공

김 솔 비

본 연구는 골프 스윙 시 왼쪽 고관절 내회전 제한이 있는 프로 골퍼와 제한이 없는 프로 골퍼 간의 요골반부의 움직임의 차이를 알아보고자 하였다.

연구대상자는 15명의 왼쪽 고관절 내회전에 제한($<20^{\circ}$)이 있는 프로골퍼들과 유사한 나이의 고관절 내회전에 제한이 없는($>30^{\circ}$) 프로 골퍼들 15명이었다. 3차원 동작 분석기를 이용하여 골퍼들의 움직임을 측정하였고, Biodex를 통해 체간 굴곡근, 신전근의 근력을 검사하였으며 고관절 회전 근력은 도수근력측정장비를 통해 평가하였다. 또한 Thomas 검사와 하지직거상 검사를 통해 양측 고관절 굴곡근과 슬와부근의 근육 길이를 측정하였다. 골프 스윙은 총 10회를 치게 하였으며 그 중 임팩트 순간 공의 속도가 가장 빠른 5개를 선택하여 분석하였다. 통계방법으로, 독립표본 t-검정은 두 집단간의 요골반

부의 움직임, 체간 근력, 고관절 회전 근력, 슬와부근의 근육 길이의 평균차이를 검증하기 위해 사용하였으며, Mann-Whitney U 검정을 통해 고관절 굴곡근 길이 차이를 검증하였다. 상관분석은 왼쪽 고관절 제한과 골프 스윙 마지막 단계에서의 골반의 회전 각도의 상관관계를 확인하기 위해 사용하였다. 모든 통계학적 유의수준은 $\alpha=0.05$ 로 정하였다. 독립표본 t-검정 결과 고관절 내회전이 제한된 골퍼들은 오른쪽 굴곡근과 슬와근의 근 길이가 상대적으로 단축되어 있음을 확인할 수 있었으며($p<0.05$), 왼쪽 내회전 근력과 오른쪽 외회전 근력이 제한이 없는 골퍼에 비하여 유의하게 약하였다($p<0.05$). 공의 최대 속도는 비슷하지만, 요부의 굴곡, 회전, 측면 굽힘 동작은 제한된 골퍼들이 크게 나타났다($p<0.05$). 골반의 움직임은 다운스윙 시 제한된 골퍼들은 건강한 골퍼들보다 더 큰 후방 경사 움직임을 보였으며($p<0.05$), 마지막 동작에서 골반 회전 움직임이 상대적으로 작게 나타났다($p<0.05$). 마지막 동작에서의 골반 회전 움직임의 제한과 고관절 내회전 각도는 정적 상관관계가 있었다($r=0.60$, $p<0.05$). 이 결과들을 종합하면, 고관절이 내회전 제한된 프로 골퍼는 골프 스윙 시 요부에 더 큰 움직임과 골반부에서는 비정상적인 움직임 패턴을 초래함을 알 수 있었고, 이는 요통의 발병 원인의 주요한 인자로 작용하게 될 것이라 사료되는 바이다.

핵심 되는 말: 고관절 내회전 제한, 골프, 요골반부 움직임, 요통.