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CORRELATION BETWEEN PASSIVE AND DYNAMIC RANGE OF ROTATION IN LEAD AND TRAIL HIPS DURING A GOLF SWING

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ABSTRACT

The aim of this pilot study was to determine the association between the passive range of motion versus golf dynamic rotation range of both the lead hip and trail hip of healthy adult male golf players. Seven skilled male golfers between the ages of 18 and 40 years were selected randomly. Passive hip rotation range of movement (ROM) measurements were collected with a hand-held inclinometer. Dynamic kinematic hip rotation data were captured with a high-speed opto-electric 3-D motion capture system during a golf swing. There was a positive correlation (r= 0.42) between the passive hip ROM and dynamic hip range of movement during the golf swing of the lead hip, but the correlation was not significant (p= 0.34). There was a weak negative correlation (r=-0.05) that was not significant (p= 0.9) between the passive hip range of movement and dynamic hip range during the golf swing of the trail hip. Clinicians and coaches should thus note that improving passive hip ROM might not be associated with an increased hip rotation utilised during the golf swing.

Key words: Lower limb rotation; Golf swing biomechanics; Hip kinematics; Lower back pain.

INTRODUCTION

The golf swing involves a sequence of complex multi-segmental movements (Keogh & Hume, 2012). This smooth and well-timed, sequence of body movements mainly occurs in the transverse plane (Cabri *et al*., 2009). The golf swings commences from the address posture, the starting position when the golfer faces the ball. The typical golf swing is executed in three main phases, backswing, downswing and the follow-through phase. In order to propel the ball forward towards the target, the golf swing requires powerful movement of the spine, shoulders and hips (Keogh & Hume, 2012).

The hip joint acts as the main driver during the golf swing because it initiates the movement from the address posture (Hume *et al*., 2005; Healy *et al*., 2011). As the swing continues, hip rotation precedes movement of the arms and spine. The hips continue to rotate until the end of the follow through phase (Keogh & Hume 2012). The hip joint also acts as a pivot between the upper and lower body segments to facilitate synchronised movements during the golf swing. Therefore, appropriate hip movement is critical for successful execution of the golf swing.

Inadequate hip rotation may be associated with golf related back pain. Back pain affects one in three golfers (Murray *et al*., 2009). It is postulated that reduced passive hip rotation place increased and repetitive strain on the lower back structures, which eventually leads to pain (Murray *et al*., 2009; Gulgin, 2012). Murray *et al*. (2009) illustrated that golfers with back pain have reduced passive and active lead hip (LH) internal rotation (IR), compared to golfers without back pain. Asymmetrical total hip rotation range, between the lead and trail hips, is also associated with back pain (Gulgin, 2005; Van Dillen *et al*., 2008). Sportspersons who regularly partake in a sport that requires repetitive rotation between the trunk and pelvis have also been shown to have limited LH total range of hip rotation compared to that of the trail hip (TH) (Van Dillen *et al*., 2008). Reduced total range of hip movement may thus predispose golfers to overuse problems, such as back pain, although the optimal hip range during the golf swing remains unknown.

Clinically, non-weight bearing total passive and active hip range of motion is utilised to estimate whether a golfer has adequate hip range for proper execution of the golf swing. Traditional methods to measure hip range in sitting, supine or prone positions are reliable. However, to date it is unknown whether this clinical method for measuring hip range is also a valid assessment of the amount of rotation required during the actual golf swing. In addition, it is uncertain whether passive hip rotation range is correlated with the amount of hip rotation used during the golf swing. Such knowledge will assist coaches and clinicians to optimise rehabilitation programmes post injury or to enhance performance.

PURPOSE OF STUDY

To our knowledge, there is no information about the correlation between clinical hip rotation assessments and the amount of hip rotation utilised by a golfer during a golf swing. The main aim of this pilot study was to determine the association between the total passive range of motion (ROM) and golf dynamic rotation ROM of both the lead hip (LH) and trail hip (TH) during the golf swing in healthy adult male golf players. In addition, the proportion of hip passive range utilised during the golf swing was determined. This study also provides preliminary data and feasibility information for similar larger studies in this field.

METHODOLOGY

Study design

A descriptive study was conducted. A preliminary, reliability study was conducted to ascertain the reliability of using an inclinometer to measure passive hip rotation movement.

Sample recruitment, size and description

An acquired candidate list form from the Western Cape (WC) region of golf academies and clubs was randomised. Candidates from the list were contacted telephonically in a descending order. Whilst answering the first section of the questionnaire telephonically, eligibility was established. A sample size of 7 participants was recruited for this pilot. Resources and the exploratory nature of the pilot study limited the sample size. A sample size calculation was not possible due to non-existence of similar studies or pilot data on which a sample size calculation can be based.

Male golfers aged between 18 and 40 years with normal waist-hip ration (WHR) and a handicap of 16 or lower were eligible to participate. Participants had to have played golf for at least 2 years, and play an 18 hole-round of golf per week and continue practising 3 or more hours per week on the golf range or greens. Candidates were excluded if any musculo-skeletal injury, pain, surgery or fractures to the spine, upper or lower extremities were present. Participants with hip abduction ROM less than a normal 30° and hip flexion less than a normal 105° were also excluded. None of the participants had abnormal hip ROM, based on clinical passive ROM assessment.

Ethical clearance

The study received approval from the Health Research Ethic Committee at Stellenbosch University (no. S12/11/272). Informed consent was obtained from each participant.

Instrumentation

Total passive hip rotation range of motion

Total passive hip rotation range of motion was measured with a plastic Baseline® Bubble hand-held inclinometer. The inclinometer reliability was better than that of a digital inclinometer or goniometer (Bierma-Zeinstra *et al*., 1998). A hand-held inclinometer is user-friendly for clinical utility. The validity and reliability of a hand-held inclinometer were found to be excellent while measuring passive hip ROM (Boyd, 2012).

Total dynamic hip rotation range of motion

Total dynamic hip rotation range of motion during a golf swing was measured using an 8 camera T-10 Vicon (Ltd) (Oxford, UK) system with integrated software, Nexus 1.8. The Vicon motion analysis system is a 3-dimensional (3-D) opto-electrical motion capture system, which is widely used in a variety of ergonomics and human factor applications. The 3-D motion analysis technology is regarded as the gold standard for 3-D analysis of movement due to the good reliability and validity and measurement errors of less than 2º in the transverse plane (Kadaba *et al*., 1990; Tsushima *et al*., 2003).

Preliminary reliability study

A preliminary study was completed to determine the investigator intra-rater reliability for total inclinometer passive hip articular range measurements. Eight golfers, aged 17 to 35 years, who met the inclusion criteria of the study, participated in the reliability study. Measurements were taken at the end of a practice day. Prior to the measuring procedure, each participant performed 2 supervised hip rotation stretches (a standing stork stretch and standing sit-squat stretch), chosen to enhance the surrounding soft tissue for hip flexibility (Tamai *et al*., 1989; Evans *et al*., 2005; Kurihashi *et al*., 2006). Seated measurement positions, were done as described in a later section. Three measurements of the total passive range of each hip (LH, TH) were measured 2 minutes apart in each participant. The hip joint was returned to neutral before the following ROM was recorded.

Procedures

Questionnaire and data collection sheet

After eligibility was obtained telephonically, the data sheet of the following sections in the questionnaire was completed during an interview prior to the passive procedures. The questionnaire included questions regarding the participant's personal details and demographics, as well as their medical, golf, family, physical conditioning and sport participatory history. The study was conducted in the Biomechanical Laboratory at Stellenbosch University. Participants were familiarised with the laboratory environment and equipment, and then debriefed regarding the testing procedure.

Passive hip rotation range of motion measured in sitting

Participants were dressed in knee-exposing, non-restrictive clothing without shoes. Prior to the passive range of movement assessment, a 10-minute stationary bicycle warm-up was completed. Participants sat on the firm medical plinth, set at an 85cm height. A 45° angled plastic-covered wedge was added as back support and a pelvic belt was placed over the anterior iliac spine and strapped to the plinth to prevent any pelvic movement during passive hip rotation (Figure 1). The contra-lateral foot was placed on the plinth, leaving the hip in full flexion, thereby stabilising the hip and pelvis, which was being measured. The thigh of the measured hip was positioned on the plinth and measured at a 135° hip-trunk angle (leaning backwards position), to replicate the hip's position during the address position (Hume *et al*., 2005). The fibular head was marked with a skin marker, as this point was used for the inclinometer placement (Figure 2).

FIGURE 1. **SEATED POSITION FOR INCLINOMETER HIP ROTATION MEASUREMENTS**

FIGURE 2. **INCLINOMETER PLACEMENT FOR HIP ROTATION MEASUREMENTS**

The investigator sat on a 25cm high gym step in front of the participant, facing the knee at eye height level. Total hip rotation was performed passively from a firm end-feel at the top of the one end of the range was felt until the same firm end feel was felt at the other end of the range, or any pelvic compensatory movement was noted. The hip was returned to the mid-position before external rotation and then internal rotation was recorded separately. Each of the 3 movements was performed in the same order for each participant.

Anthropometric measurements

Anthropometric measurements were recorded as required for a VICON-analysis. The participant's stature, mass, leg length, shoulder offset, hip circumference, hand thickness, as well as the width of the wrist, elbow, knee and ankle were recorded using an anthropometer and digital scale.

Dynamic hip rotation range of motion measured during a golf swing

All reflecting clothing or objects were either removed or covered to prevent interference with the opto-electric 3-D motion capture-system. A lower limb retro-reflective marker set was placed on bony landmarks by a physiotherapist experienced in marker placement and who had training for this according to the conventions of the Plug-in-Gait, lower limb model (Figure 3). System calibration was achieved according to standard VICON procedures. Model calibration was captured with the participants assuming a standard standing T-position. Soft golf balls were used for ball-impact for the purpose of protecting the laboratory equipment. Each participant used his own 7 iron and golf shoes. Five to 10 practise swings were allowed prior to the testing procedure. A series of 10 swing-trials were performed for data collection purposes. Verbal instructions (Table 1) were given to each participant prior to each of the 10 captured golf swings. The total range of hip rotation was calculated using the Plug-in-Gait model and filtered with a 4^{th}-order Butterworth filter at a 10Hz cut-off frequency.

TABLE 1. **GOLF SWING INSTRUCTION TO PARTICIPANTS**

Description of swing movement	**Instructions**
Face down the line holding their own 7-iron club; each subject wearing his own golf shoes	"Address your ball in the manner most common to the start of your swing."
Three golf swings (full back swing to full final phase) was practised to instil a normal practice swing while the soft ball was in place	"Take a few practise swings to familiarise yourself with the lab environment and get a feel for the soft ball."
A full swing was captured 10 times (from address to finish phase). The Bio-statistician provided a starting nod for each participant	"Get ready to take a full swing, aim for the centre of the wall at the back of the lab."
Encourage the participants to walk away and re-address the ball each time he swings ensuring the most natural swing he could mimic in the lab set-up.	"Relax, and walk away from the starting point, take care not to bump any equipment please." "Repeat the swing again." (until 10 trails is reached)

FIGURE 3. **LOWER BODY RETRO-REFLECTOR MARKER PLACEMENTS: ANTERIOR, LATERAL AND POSTERIOR VIEWS**

Data analysis

The outcomes were passive hip ROM during a seat-adjusted position and dynamic hip ROM measurement during a golf swing. Microsoft Excel and STATISTICA version 10 were used to analyse the data. To determine inclinometer intra-rater reliability, a 2-way Interclass Correlation Coefficient (ICC), standard error of measurement (SEM) and a 95% confidence interval level was calculated. ICC values of between 0.85 and 1.0 were considered good reliability. For the descriptive statistics, the mean was used as a measure of central location and standard deviations as indicators of variability. Spearman correlation coefficients (r) were calculated and scatter plots were used to express the correlation between total passive ROM and total dynamic ROM. T-tests were used to test for difference between the lead and trail passive hip ROM, as well as between the dynamic hip ROM of the lead and trail hip. A probability value of $p<0.05$ was set for the statistical significance for all tests.

RESULTS

Participant demographics

TABLE 2. **PARTICIPANT DEMOGRAPHICS**

Variables	**Mean±SD**
Age (years)	26.5±8.1
Height (cm)	176.9±5.1
Mass (kg)	79.1±13.5
HRT/7	13.2±5.9
HC	1.0±1.0
WHR	0.9±0.9

HRT/7= hours training per week HC= Handy-cap system WHR= Waist-hip-ratio

The descriptive data of the participants (N= 7) is summarised in Table 2. All participants were right-handed players. The mean age at which the participants started playing golf was 9.7±4.1 years. None of the participants had upper limb, lower limb or musculo-skeletal complaints of the spine in the past 12 months. The WHR measurements were within normal limits (0.9±0.06).

Reliability of passive ROM measurements

The ICC for passive ROM was 0.81 (95% CI: 0.46-0.96) and the SEM was 3.02 for the intra-rater reliability.

Passive hip ROM

TABLE 3. **LEAD AND TRAIL HIP: MEAN PASSIVE AND DYNAMIC ROM IN DEGREES AND PERCENTAGE UTILISED**

	Passive ROM°	**Dynamic ROM°**	***Difference°**	**% Utilised**
Lead hip				
P1	60.0	30.9	29.1	51.5%
P2	55.0	27.2	27.8	49.5%
P3	70.0	36.5	33.5	52.1%
P4	65.0	36.7	28.3	56.4%
P5	70.0	29.5	40.5	42.1%
P6	55.0	19.9	35.1	36.2%
P7	60.0	22.3	37.7	37.2%
Mean±SD	62.1±6.4	29.0±6.5	33.1±5.0	46.4±8
Trail hip				
P1	60.0	43.6	16.4	72.7%
P2	66.0	23.5	42.5	35.6%
P3	60.0	35.2	24.8	58.7%
P4	64.0	43.1	20.9	67.3%
P5	60.0	43.1	16.9	71.8%
P6	65.0	33.4	31.6	51.4%
P7	55.0	29.6	25.4	53.8%
Mean±SD	61.4±3.8	35.9±7.8	25.5±9.2	58.8±13

P= Participant *Difference between total passive range and dynamic range during swing °= Degrees

Passive hip ROM of the lead and trail hip

There was no significant difference between the lead and trail passive hip ROM ($p=0.8$) (Table 3). Four of the participants had a passive ROM asymmetry of 10 degrees or more between the 2 hips.

Dynamic hip ROM during the golf swing of the lead and trail hip

There was a statistically significant difference (p=0.04) between the dynamic hip ROM of the lead and trail hip (Table 3). Three of the participants demonstrated a dynamic hip ROM asymmetry of 10 degrees or more between the 2 hips during the golf swing.

Range difference between passive hip ROM and dynamic hip ROM during golf swing

A male golfer utilised 46.4% of the mean passive lead hip total ROM while in the trail hip, he utilised 58.8% (Table 3). The difference between passive hip ROM and dynamic hip ROM during the swing is reported in Table 3. The difference between the passive and dynamic hip ROM ranged between 27.7 to 40.5 in the lead hip and 16.4 to 42.5 in the trail hip (notably larger than the SEM). In the trail hip, a bigger variability was noted when the ROM difference was compared to the lead hip.

Correlation between passive hip ROM and dynamic hip ROM during golf swing

Lead hip: Correlation between passive hip ROM and dynamic hip ROM during golf swing

There was a positive correlation (r= 0.42), albeit insignificant (p=0.34), between the passive hip ROM and dynamic hip ROM during golf wing of the lead hip (Figure 4).

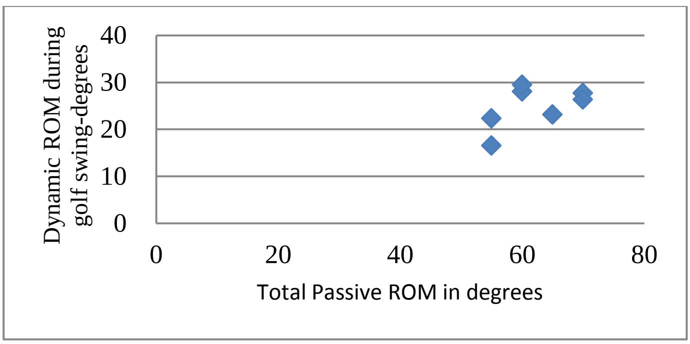

FIGURE 4. **LEAD HIP**

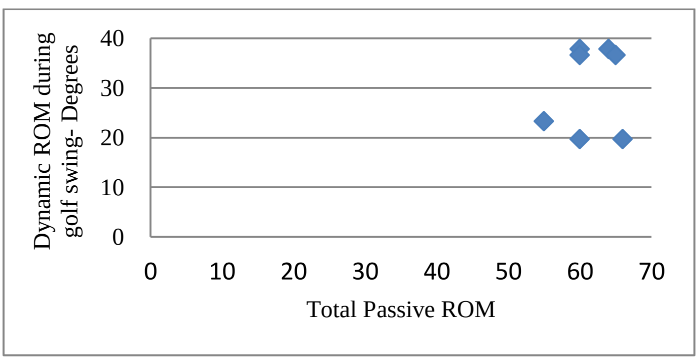

FIGURE 5. **TRAIL HIP**

Trail hip: Correlation between passive and dynamic hip ROM during golf swing

There was an insignificant (p=0.90) and weak negative correlation (r=-0.05) between the passive hip ROM and dynamic hip ROM during the golf swing of the trail hip (Figure 5).

Correlation between lead and trail hip passive hip ROM

There was an insignificant (p=0.19), moderate negative correlation (r=-0.55) between the lead and trail hip total passive ROM.

Correlation between lead and trail hip dynamic hip ROM during the golf swing

There was an insignificant (p=0.78) and weak positive correlation (r= 0.12) between the lead and trail hip total dynamic ROM during the golf swing.

Graphic illustration of the golf swing

The following graphics present an illustration of the kinematic pattern of the group mean as reported in the lead hip (Figure 6) and trail hip (Figure 7).

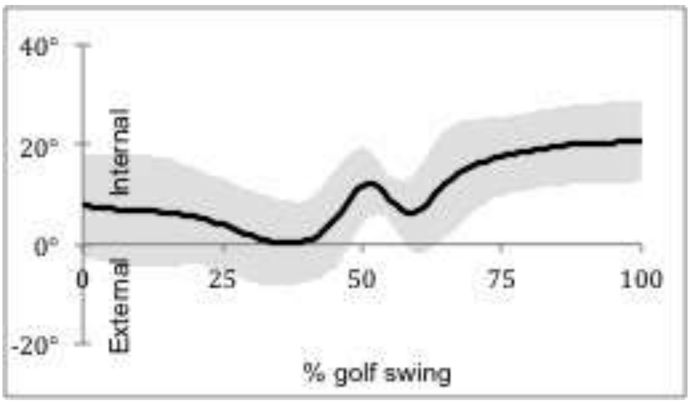

FIGURE 6. **LEAD HIP ROTATION DURING A SWING**

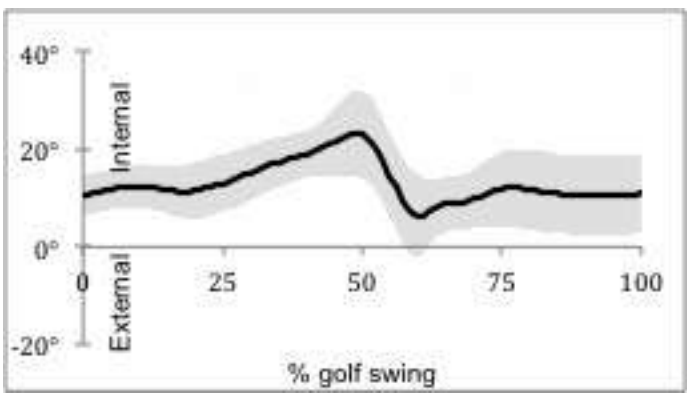

FIGURE 7. **TRAIL HIP ROTATION DURING A SWING**

DISCUSSION

This pilot study provides the first information on the correlation between passive hip ROM (a common clinical method for measuring hip range in golfers), and actual hip ROM during the golf swing.

Participant demographics

In the sample, the waist-hip ratio (WHR) was considered part of the participant eligibility criteria as it provides an indication of the body fat percentage. Participants with a high obesity index would have been excluded from this study sample, as it would have influenced the degree of hip rotation.

Kouyoumdjian *et al*. (2012) investigated the relationship between hip rotation and the WHR. WHR measures central adiposity in participants. A hip loses 0.98° of rotation ($p<0.0006$) for each fat percentage-unit that increases. Therefore, the WHR-method was considered as part of the participant eligibility criteria as it provides an indication of the body fat percentage. Participants with a high obesity index were excluded to assure sample homogeneity with respect to WHR.

Handicapping a golfer is an effective equalizer among golfers with different abilities. A golf handicap (HC) system (Table 4) is based on the assumption that in every 9- and 18-hole stroke played by a golf player, he/she will endeavour to achieve the best score at each hole played and will report this score to the South African Golf Association within a 24 hour period, regardless where the round of golf was played. The current sample has an average HC of 1 (±0.8), which illustrate that they play golf regularly.

TABLE 4. **PURPOSE OF HANDICAP (HC) SYSTEM**

- Provides all golfers with a fair HC;
- Reflects the player’s inherent ability and trends to his recent score;
- Has the ability to adjust an HC to a player’s ability;
- Disregards freak high scores that bear no relation to the player’s normal ability;
- Establishes handicaps for all golfers, from informal play to championships;
- Assists a handicapper to identify a player whose handicap does not reflect playing ability.

The mean age for the study group was 26.6±8.2 years. Gosheger *et al*. (2003) reported in their study regarding injuries and overuse syndromes in golfers that the average age of golfers was 46 years, and most have been playing golf for approximately 10 years. Gosheger *et al*. (2003) studied a larger group of 703 golfers and, therefore, this age group may represent the population of golfers better than it may represent the participants in the sample of the current study.

Total passive hip ROM

Concurrent with the findings of the current study, excellent inclinometer reliability measurement in a study measuring hip flexion range during straight leg raising tests, the standard error of measurement was between 0.54 and 1.22 and the minimal detectable change was between 1.50 and 3.41 (Boyd, 2012). This author also reported a low variability and excellent validity for a hand-held inclinometer. This illustrates that the differences found between the passive hip ROM and dynamic ROM during the golf swing due to measurement error is not likely in the current study, as the differences were much larger than the measurement error.

In young male golfers, this was reported as 62.2±6.4 in the lead hip and 61.5±4.0 for the trail hip. Murray *et al.* (2009) reported the prone passive inclinometer hip range in golfers as 73° in the lead hip and 78° in the trail hip. The larger rotation range of ±15° could be explained by the fact that the reported ROM included males and females in the study group. It has been reported that female subjects, irrespective of age, had between 16 to26° more rotational mobility than their male counterparts did (Soucie *et al.*, 2011). Due to this, a male-only population was included in the present study. Soucie *et al.* (2011) reported that female golfers' passive inclinometer hip ROM in a lead hip was 93.3±17 and in the trail hip it was 92±19. Both of these studies reported larger ranges than the male-only sample in the current study.

Regardless of gender or side, seated passive hip ROM in a normal non-golfing population was reported to be 78.5±11 (Kouyoumdjian *et al.*, 2012) and 76.5 (Bierma-Zeinstra *et al.*, 1998). These ranges fell well within the passive range measured for golfers in the current study. However, possible differences could be attributed to measurement techniques, joint positions or measuring instrumentation. A slight tightening of the strong and dense hip capsule could be expected to be reached in the seated hip extension (135° trunk-hip position) posture, as position towards full hip extension will tighten the joint capsule (Norkin, 1992).

Dynamic hip ROM during golf swing

In published reports, the angle measured between the hip axis (pelvis) and the shoulder axis is described sometimes as the amount of hip rotation taking place during a golf swing (Burden *et al.*, 1998; Hume *et al.*, 2005; Myers *et al.*, 2008). This measurement of hip rotation represents pelvic rotation in relation to shoulder axial rotation. In the current study, femoral acetabular hip rotation during the golf swing using the VICON plug-in-gait model was measured.

The mean dynamic hip ROM in male golfers in the current study reported the lead hip rotation as 29±6.5 and the trail hip as 35.9±8 during a golf swing (Table 3). The active weight bearing hip range in a rotation-related sport, such as golf, occurs in a closed kinetic sequence. Gulgin *et al.* (2010) discovered that the weight-bearing rotation ROM measured was 64.5° in the lead hip and 23.8° in the trail hip range. These measurements were taken by a VICON system on a group of female golfers in a standing closed kinetic chain position. These results indicated that hip rotation ROM in a golfer adapts according to the imposing physiological demands.

In the current study, 2 of the golfers had less than the mean dynamic articular range in the lead hip than the group average, while two golfers reported 10 degrees more. Two of participants had less dynamic ROM in the trail hip than the group average, while three participants had 5 degrees more than the average (Table 3). This indicates variation in hip rotation among young golfers with similar profiles. All coaches and clinicians should thus consider individual variation.

Practical applications

The correlations between the passive hip range and dynamic hip range during the golf swing were not significant and produced weak correlation values. The interpretation of this finding is clinically significant for physiotherapist, biokineticists and sport trainers who engage in the rehabilitation and performance of golfers. The findings of the present study imply that passive hip ROM assessment may not be a valid indicator of the amount of hip rotation utilised during the golf swing. The before dynamic assessment of hip ROM is the optimal marker for establishing the amount of hip rotation utilised by a specific golfer. In addition, the findings suggest that simply improving passive hip ROM will not naturally translate into increased dynamic hip ROM during the golf swing. Many other factors, such as sensorimotor control and relative flexibility, may influence the amount of hip rotation utilised during the golf swing. These findings highlight the principle of specificity that should be applied in the rehabilitation or performance enhancement of the golf swing in golfers.

LIMITATIONS AND RECOMMENDATIONS

Although the results provide valuable information and insight into the relationship that exists between the passive and dynamic hip rotation, there are several limitations. A larger sample size is required in future studies. Sample size calculations can be conducted now based on the preliminary findings of this study. The inclinometer reliability study did not use a blinded measurer, and inter-tester reliability was not performed and should be considered for future studies. Due to limited resources, the hip joint integrity was not investigated (MRI, x-rays and sonars), but could be considered. Possible kinematic influences from the knee and foot were not assessed, but it could play a role in influencing the kinematic chain of the lower limb.

In addition to addressing the limitations as outlined, the influence that the hip joint flexibility has on hip mobility in a golfer would be of great clinical value. Comparing low handicap golfers to higher handicap golfers could be valuable in exploring the effect a golfer could expect on his lumbar spine after long periods of intense exposure to a rotation related sport. A normative database for dynamic hip rotation ROM in a golfer's hip joint should be established, which can assist in classifying the golfer according to their degree of rotation and subsequent risk of injury. Investigation into golfers with pathologies, injury or pain in the lower back should be conducted. This could provide insight into rotational factors associated with musculo-skeletal problems that golfers may experience.

CONCLUSION

This study provides preliminary information about the correlation between passive hip ROM and dynamic hip ROM during the golf swing. There were insignificant and weak correlations between the passive hip range and dynamic hip range during the golf swing. Clinicians and coaches should thus note that improving passive hip ROM might not increase the amount of hip rotation during the golf swing. Future research should be conducted with larger samples.

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