RELATIONSHIP BETWEEN ANKLE MOBILITY AND GOLF SWING KINEMATICS

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The purpose of this study was to examine the relationship between ankle mobility and golf swing kinematics. Ankle mobility was assessed using the weight bearing lunge test and three-dimensional kinematic data from 10 golf drives were collected using a Vicon motion capture system. Pearson's correlation coefficients were calculated to identify the relationship between ankle mobility and the rotations of four segments; pelvis, shoulders, upper arm and forearm. Large positive relationships were identified for the rotations of the pelvis (r = 0.670*)* and shoulders (r = 0.604) in the downswing as well as for peak rotational velocities of the pelvis (r = 0.553), shoulder (r = 0.571) and upper arm (r = 0.549) segments. These results indicate that improvements in ankle joint mobility are associated with superior rotations of segments further up the kinetic chain and that the weight bearing lunge test should be used as part of golf specific movement screening.

KEYWORDS: weight bearing lunge test, kinetic chain, movment variability.

INTRODUCTION: The golf swing has been recognised as one of the most difficult biomechanical motions in sport to execute and master. It can appear effortless and graceful in the hands of an expert but awkward and jerky for the novice. During the swing, golfers form an open kinetic chain with the feet at the closed end, the clubhead at the open end and several body segments in between. The complexity of the golf swing is often associated with the necessity to coordinate these body segments - as the outcome of any golf swing, is extremely sensitive to small variations in timing, tempo and rhythm.

The proximal-to-distal sequence has become an important theme in golf swing research and has frequently been linked with skilled golf performance. It has been suggested that, golfers utilise sequential rotations of the pelvis and upper trunk and a late release of the arms to produce fast and consistent golf swings (Myers *et al*., 2008). These sequential rotations can enable golfers to take advantage of the mechanical benefits of the summation of speed principle as well as the muscular advantages associated with the stretch shortening cycle.

Breakdowns in the kinetic chain such as reduced flexibility and poor movement mechanics have previously been shown to impair energy transfer and kinematic performance. For example, during a loaded back squat, restricted ankle functionality was associated with reduced knee flexion and increased valgus. Furthermore, reduced ankle dorsiflexion during a step-down test was related to higher magnitudes of hip adduction and internal rotation (Bell-Jenje et al., 2016). This suggests that restricted functionality of segments at the closed end of a kinetic chain can have direct effects on segments further up the kinetic chain.

In the golf swing, the pelvis has frequently been identified as the proximal end of the kinetic chain. However, skilled golf performance also relies on the interaction between the feet and the ground and includes ankle dorsiflexion, foot inversion and pronation. It has been suggested that plantar and dorsiflexion of the ankle joints (Rogers et al., 2004) and the generation of ankle plantarflexion torques in the early downswing (Takagi et al., 2019) help to facilitate the rotational movements of the pelvis and shoulders in the transverse plane. Furthermore, in golf swings performed by trans-tibial amputees, increased prosthetic torsional stiffness in the sagittal plane reduced rotation of the hips and shoulders during the backswing and downswing (Rogers et al., 2004). However, the importance of the ankle joint functionality has yet to be examined in the swings of able-bodied golfers. Therefore, the aim of this study was to examine the relationship between ankle mobility and golf swing kinematics.

METHODS: Sixteen male golfers participated (M ± SD; age, 26 ± 13 years; height 1.79 ± 0.07 m; mass 76.5 ± 16.2 kg; handicap 4.8 ± 4.2 strokes and club head velocity 108.2 ± 8.1 mph). All golfers reported no lower extremity injury in the previous six months, no lower extremity

surgery and no health conditions which influenced ankle function. Ethics approval was granted by the School of Human Sciences Research Ethics Committee.
The weight-bearing lunge test (WBLT) provides a valid assessment of ankle dorsiflexion range of motion and an indication of overall foot and ankle motion. The WBLT was performed using the knee-to-wall principle with subjects in a standing position facing a wall. The test foot was parallel with a tape measure secured to the floor with the second toe and centre of the heel, and perpendicular to the wall. The opposite limb was positioned approximately 1-foot length behind the test foot. While in this position, the subject lunged forward until the anterior knee contacted the wall and maximum dorsiflexion was obtained. The same investigator administered the WBLT across all subjects and the average of three trials for each limb were included for statistical analysis.
Three-dimensional coordinate data were collected using a 12-camera Vicon motion capture system (Vicon, Oxford, UK) sampling at 240 Hz. Thirty-four reflective makers were attached to specified anatomical landmarks. Two further markers were attached on the golf club. Sufficient time was given for golfers to perform their usual pre-game warm-up and become familiar with the laboratory environment and data collection protocol. Following static and dynamic calibration trials, participants performed 10 full golf drives from an artificial matt into a net 5m away. Participants wore golf shoes and used their own driver. A pole was placed behind the net as a target and club head speed was measured using a launch monitor (Ernest Sports).
Marker data were filtered using a Woltring filter routine and analysis was performed on the top five trials with regards to club head speed. The magnitude of maximum ankle dorsiflexion was identified for the lead and trail legs and segment rotations were calculated for four segments; pelvis, shoulder, upper arm and forearm. Segment rotations were defined with regards to the global coordinate system in a manner consistent with the recommendations of the ISB and the component of rotation around the superior-inferior axis was reported. Golf swings were divided into two phases, backswing and downswing which were defined by three events, take-away, top of backswing and ball contact. The magnitude of segment rotation was calculated for both phases and the x-factor and x-factor stretch were also calculated. Peak rotational velocities in the downswing were identified for each segment along with the lag between the timing of maximum rotational velocity for a proximal segment compared to its distal neighbour.
All statistical analyses were performed using SPSS Version 26.0 (SPSS Inc., Chicago, IL, USA). Pearson's correlation coefficients were calculated to identify the relationship between the results of the weight bearing lunge test, dynamic maximum ankle dorsiflexion in the golf swing and each of the dependent variables. Statistical significance was established as $p < .05$.

RESULTS: There was a strong positive relationship between WBLT score and the magnitude of peak lead ankle dorsiflexion (r = 0.608, p = 0.012) (Figure 1). Furthermore, peak lead ankle dorsiflexion had a strong positive relationship with club head speed (r = 0.565, p = 0.023) (Figure 1). In contrast, only weak correlations were identified between the magnitude of peak trail ankle dorsiflexion, WBLT score (r = 0.104, p = 0.702) and club head speed (r = 0.058, p = 0.832). In the backswing, the WBLT score had a strong positive relationship with the amount of shoulder rotation (p = 0.614, p = 0.06) but only weak correlations were found between the WBLT, maximum ankle dorsiflexion (lead and trail ankles) and all other dependent variables.

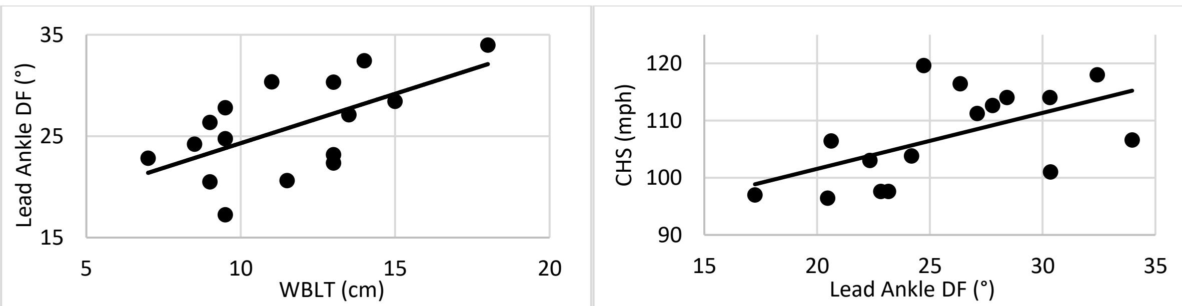

Figure 1: Left: Correlation between WBLT and lead ankle dorsiflexion (DF), Right: Correlation between lead ankle dorsiflexion and club head speed.

In the downswing, strong positive relationships were identified between WBLT scores and the magnitude of pelvis (r = 0.670, *p* = 0.01*)* and shoulder (r = 0.604, *p* = 0.01) rotations. Peak lead ankle dorsiflexion also had a strong positive relationship with the magnitude of pelvis rotation in the downswing (r = 0.651, *p*= 0.006). The WBLT score had strong positive relationships with peak rotational velocities of the pelvis (r = 0.553, *p* = 0.019), shoulder (r = 0.571, *p* = 0.013) and upper arm (r = 0.549, *p* = 0.014) segments (Figure 2). Strong positive relationships were also identified between peak lead ankle dorsiflexion and peak pelvis (r = 0.511, *p* = 0.043) and shoulder (r = 0.567, *p* = 0.022) rotational velocities. Weak correlations were identified between downswing rotation magnitudes, rotational velocities and dynamic maximum trail leg ankle dorsiflexion. Furthermore, only weak relationships were identified between WBLT scores, dynamic ankle dorsiflexion and the lag between the timing of peak rotational velocities of neighbouring segments.

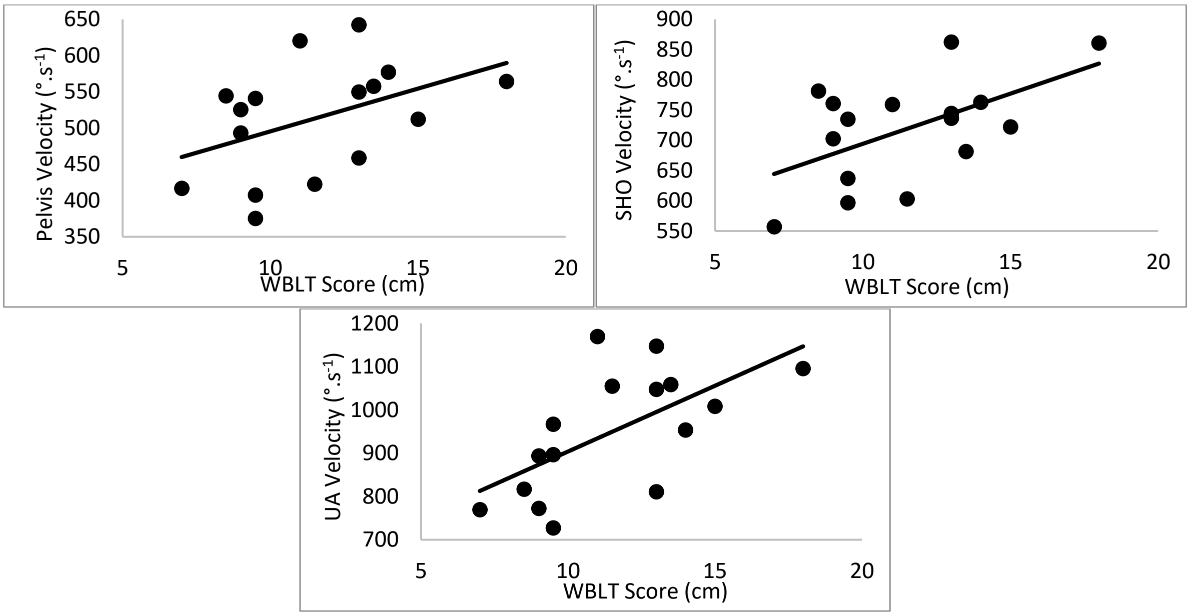

Figure 2: Correlation between WBLT score and peak rotational velocities. Left: Pelvis, Right: Shoulders (SHO), Bottom: Upper Arm (UA).

DISCUSSION: The primary findings demonstrate that ankle dorsiflexion range measured using a weight-bearing lunge test had strong positive relationships with; the rotation of the shoulders in the backswing, rotation of pelvis and shoulders in the downswing and peak rotational velocities of the pelvis, shoulder and upper arm segments. The findings also suggest that increases in WBLT score had a positive relationship with the movement of the lead ankle during the golf swing and that this golf swing specific measure of ankle dorsiflexion had strong positive relationships with pelvis rotation in the downswing and peak rotational velocities of the pelvis and shoulders. These suggestions are consistent with another study where greater ankle mobility in the form of decreased trans-tibial prosthetic torsional stiffness was associated with increases in downswing shoulder rotation (Rogers et al., 2004). Increased lower extremity function has also been associated with more coordinated movements in baseball pitching and the weighted back squat. Therefore, it is evident that, in complex movements such as the golf swing, functionality of the ankle joint measured in WBLT is inherently linked to superior movement of the ankle and rotations of segments further up the kinetic chain.

Increased ankle mobility had positive relationships with peak rotational velocities of the pelvis, shoulder, and upper arm during the downswing. Literature suggests that this would improve the transfer of energy through the kinetic chain and allow players with greater ankle mobility to benefit from the mechanical advantages of the summation of speed principle. However, increased ankle mobility did not impact club head speed. The summation of speed principle also requires the timing of peak rotational speed to occur in a proximal-to-distal sequence. Increased separation between the pelvis and shoulder segments has also been identified as

an important factor in the generation club head speed. Therefore, as ankle mobility had no effect on the x-factor, x-factor stretch or time lags between rotational peaks of neighbouring segments, unless increased ankle mobility is coupled with an improvement in golf swing technique, it will have no effect on club head speed.
No positive relationships were identified between ankle mobility and the magnitude of forearm rotation or rotational velocity. This implies that, despite proximal segment movement limitations, the most distal segment was still able to complete effective movements. Movement variability can allow performers to overcome obstacles by automatically changing the contribution of segments to the movement organisation (Davids et al., 2003). Therefore, it is likely that functional variability allowed golfers in this study to produce swings which overcame movement constraints in the proximal segments. It is also possible that the breakdown of movement at the proximal end of the kinetic chain lead to higher demand on the distal segments. This process has been termed as the “catch up” phenomenon. The risk of this phenomenon is that it places distal segments such as the elbows and wrists at a greater risk of injury, due to the increased force and torque experienced at these joints. Although this had no impact on club head speed, the reliance on arm movements has previously been associated with an out to in swing path and reduced quality of ball strike.
This study has identified the importance of flexibility in the ankle and the production of golf swing movement quality. Many screening tests have been developed to identify physical restrictions specific to the golf swing, but the only frequently used test of ankle dorsiflexion function has been the overhead squat, as used in the FMS. However, due to multiple variables that can affect this movement, the overhead squat alone does not isolate the ankle. As the WBLT has been demonstrated to have positive relationships with maximum ankle dorsiflexion of the lead leg and swing mechanics of segments further up the kinetic chain, golf professionals should include this test within screening protocols. Furthermore, golfers wishing to improve performance and mechanics should look to incorporate exercises which seek to improve ankle dorsiflexion range.

CONCLUSION: Strong positive relationships were identified between ankle dorsi-flexion range and the magnitude of rotation and rotational velocities in more distal segments, particularly the pelvis and shoulders. These results indicate that improvements in proximal joint functionality can have a positive effect on joints more distal in the kinetic chain. As no relationship was identified between ankle mobility and movement of the most distal segment or club head speed, the results also suggest that movement variability can enable golfers to compensate for restricted proximal joint function.

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