THE RELATIONSHIP BETWEEN THE INWARD PULL MOTION AND BODY MOVEMENT DURING THE DOWNSWING PHASE IN GOLF SWING

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The purpose of this study was to investigate the relationship between the inward pull motion and body movement to increase the maximum velocity of the clubhead during the downswing phase in men's driver shot. Four male professional and five male amateur golfers were volunteered as subjects (age = 37.2 ± 14.8 yrs, 1.73 ± 0.05 m, 67.5 ± 7.1 kg). A 10-camera (250 Hz) VICON system was used in an indoor motion analysis facility to capture 3D trajectories of 57 reflective markers attached to each golfer's body and the driver. The joint force about the grip, the left hand's radius of curvature, and the Cardan angles of the pelvis and the thorax were calculated during the downswing phase in men's driver shot. The results revealed that the pelvis and the thorax were bending toward the right side (Y-axis) just before impact. These movements lead to elevation in the left shoulder and consequently the left hand moves inward from the orbit of the hub path just before impact. On that occasion, it is important the thorax is facing the front (Z-axis) to elevate the left shoulder along the swing plane.

KEYWORDS: radius of curvature, joint force of the grip, driver shot.

INTRODUCTION: The velocity of the clubhead at impact is the principal factor that determines the distance that a golf ball will travel. The importance of shot distance increases as the level of competitiveness increases (Hellstrom, 2009). Therefore, it is important to understand how to accelerate the golf club. The primary model that golf researchers have used to analyse this motion is based on a double pendulum or double link system (e.g. Budney & Bellow, 1979; Milburn, 1982; Pickering & Vickers, 1999; Williams, 1967). Though Miura (2001) presents a double pendulum swing model in which an upward force is applied at the hub just prior to impact. This inward pull motion at the impact stage has been observed with some expert players. Miura found that a constant upward acceleration of the hub applied to the model during the final 40 ms before impact resulted in good agreement between the modelled and measured hand positions of a low-handicap golfer. However, this does not clarify the relationship between the inward pull motion and body movement in increasing the maximum speed of the clubhead. The purpose of this study was to investigate the relationship between the inward pull motion and body movement to increase the maximum velocity of the clubhead during the downswing phase in men's driver shot.

METHODS: Four male professional and five male amateur golfers volunteered as subjects (age = 37.2 ± 14.8 yrs, 1.73 ± 0.05m, 67.5 ± 7.1 kg). Written informed consent was obtained from the golfers. A 10-camera (250 Hz) VICON system was used in an indoor motion analysis facility to capture 3D trajectories of 57 reflective markers attached to each golfer's body and the driver (Figure 1). The 3D coordinates were expressed in an orthogonal reference frame in which the X-axis pointed to the right, the Y-axis forward, and the Z-axis upward (Figure 2). For testing sessions, each golfer was instructed to hit optimally (for distance and accuracy) as they normally would on the golf course and then performed 5 shots into a target net 5m away. The fastest of the 5 shots of each participant was analyzed. The velocity of the clubhead was calculated from the displacement of the marker on the clubhead. The joint force of the grip was calculated from the acceleration of the driver's centre of mass (CM). The left hand's radius of curvature was calculated form the velocity and acceleration of the left hand. The Cardan angles of pelvis and thorax were calculated. The angle of the segment and joint were filtered using a Butterworth filter with a cut off frequency of 10 Hz (Winter, 1990). Then the angular velocity of pelvis and thorax about the X-, Y- and Z-axis were calculated. The CM and moment of inertia of body segments were estimated from the data of Ae (Ae, Tang, & Yokoi, 1992). The golfers were divided into two groups from the maximum clubhead velocity. To analyze the differences of variables for each event and phase, means and standard deviations were computed, and intergroup differences were verified with independent t-test using Welch's t-test. The probability level for statistical significance was set at 0.05. The velocity of the clubhead after 99% time and the grip force after 96% time due to the effect of impact.

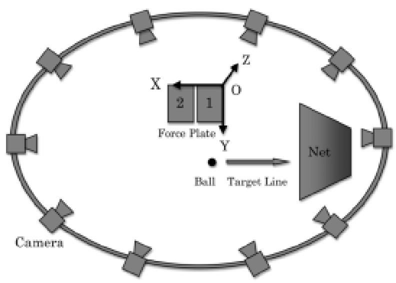

Figure 1: Experimental set-up.

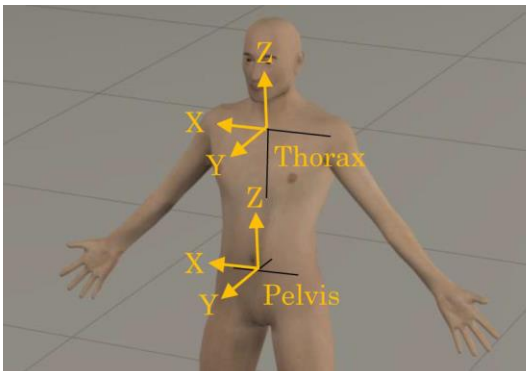

Figure 2: Coordinate system of the pelvis and the thorax segments.

RESULTS: In this study, the golfers were divided into two groups from the maximum clubhead velocity. Mean maximum clubhead velocity of the high velocity group (three professional and one amateur golfers) and low velocity group (one professional and four amateur golfers) were 48.0 ± 1.1 m/s and 43.4 ± 2.7 m/s, respectively. Mean maximum clubhead velocity was significantly different between the two groups ($p < 0.05$). There were no significant differences in the physical characteristics between the two groups ($p > 0.05$). Changes in the velocity of the clubhead, grip force and radius of curvature at left hand is shown in Fig. 3, Fig. 4 and Fig. 5, respectively. The joint force of the grip was increased from the start of downswing to impact. There was a significant difference between the high and low group after 88% time. The radius of curvature at left hand was increased from the start of downswing to 70% time. And then the radius of curvature was decreased. There was a significant difference between the high and low group from 61 to 70% time. The angular displacement of the pelvis is shown in Fig. 6. The angular displacement of the thorax is shown in Fig. 7. In the angular displacement of the pelvis, there were no significant difference about the X- axis or Z axis. There was a significant difference between the high group and low group about the Y-axis. And there was a significant difference between the two groups about the Z-axis of thorax.

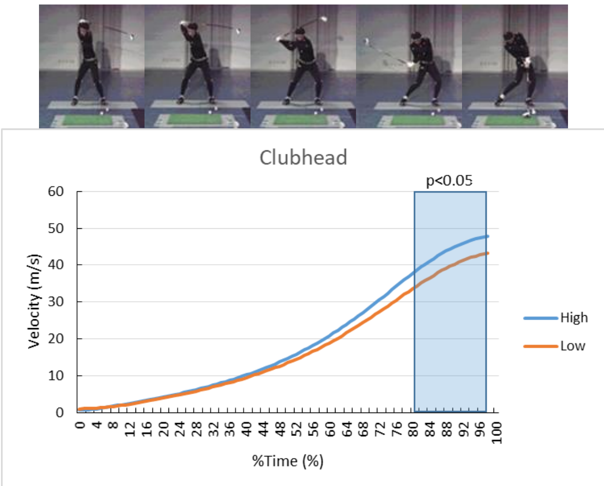

Figure 3: Changes in the velocity of the clubhead in downswing phase.

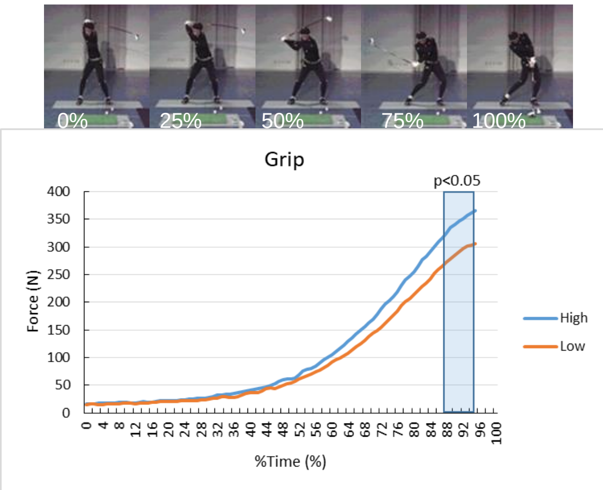

Figure 4: Changes in the joint force of the grip in downswing phase.

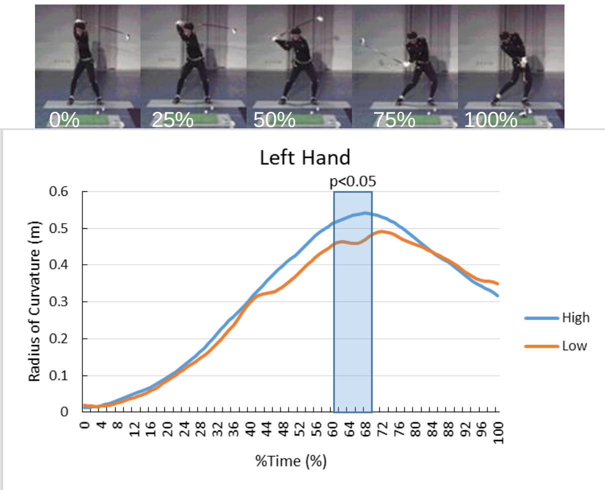

Figure 5: Changes in the left hand's radius of curvature in downswing phase.

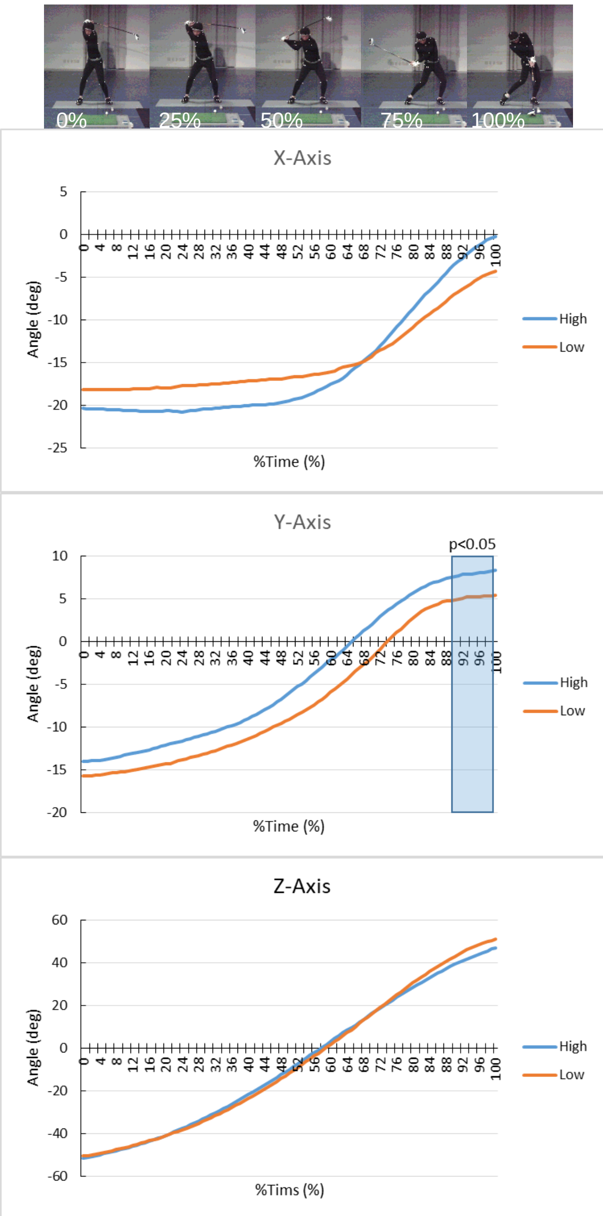

Figure 6: Changes in the angular displacement of the pelvis in downswing phase.

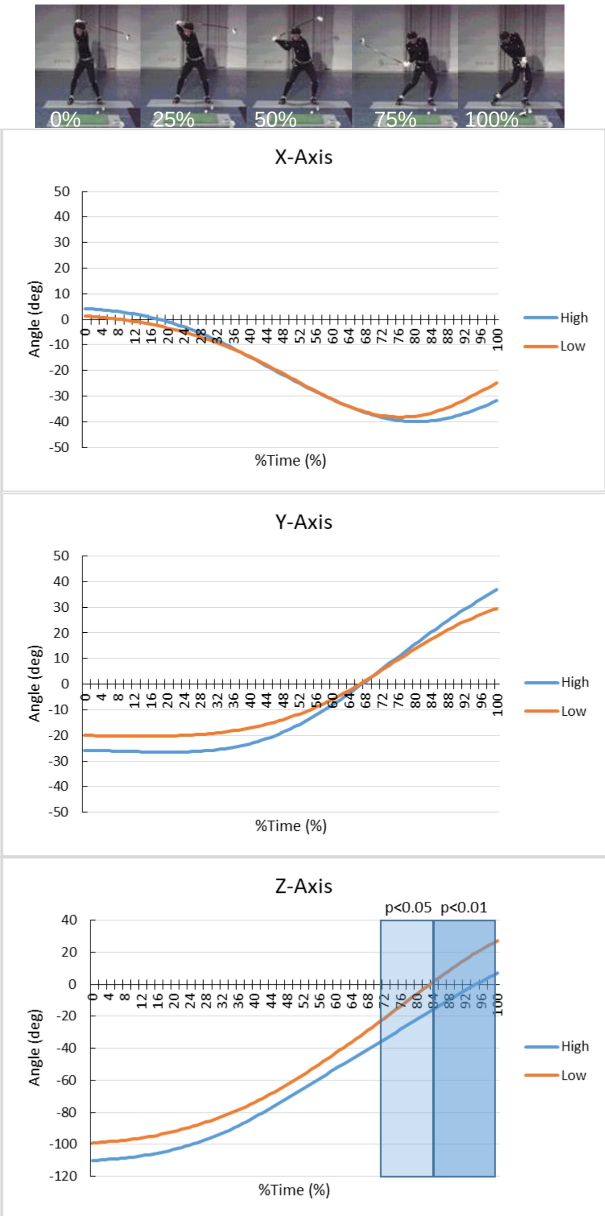

Figure 7: Changes in the angular displacement of the thorax in downswing phase.

DISCUSSION: Jacobs (2016) described that the radius of the hub path is always changing in the downswing phase. He showed the radius of the hub path was increased from the start of downswing to just before halfway down, then it decreased. It was considered that grip force acts along the club shaft. Therefore, the grip force vector point to inward from the orbit of the hub path after halfway down. And so the grip moves inward from the orbit of the hub path after halfway down. It is considered that increasing of the grip force is crucially important after halfway down to impact phase. In this study, the halfway down appeared at 0.049 ± 0.006 sec (82.8 ± 2.3 % time). The angle between the left arm and club shaft indicates approximately120 deg. Considering the grip force vector, the grip moves inward after the point that indicates the angle 90 deg between the left arm and the club shaft. This movement of the left hand is considered what Miura described as a constant upward acceleration of the hub during the final 40 ms before impact. In this study, the pelvis and the thorax were bending toward the right side (Y-axis) just before impact. These movement lead to elevation in the left shoulder and consequently the left hand moves inward from the orbit of the hub path just before impact. On that occasion, it is important the thorax is facing the front (Z-axis) to elevate the left shoulder along the swing plane. These results suggest that the large right side bending of the pelvis and thorax in the latter half of the downswing phase (the reverse K position) causes inward pull motion from the orbit of the hub path to increase the maximum velocity of the clubhead during the downswing phase in men’s driver shot.

CONCLUSION: This study identified the relationship between the inward pull motion and body movement to increase the maximum velocity of the clubhead during the downswing phase in men’s driver shot. The results revealed that the pelvis and the thorax were bending toward the right side (Y-axis) just before impact. These movement lead to elevation in the left shoulder and consequently the left hand moves inward from the orbit of the hub path just before impact. On that occasion, it is important the thorax is facing the front (Z-axis) to elevate left shoulder along the swing plane. These results suggest that the large right side bending of the pelvis and thorax in the latter half of the downswing phase (the reverse K position) causes inward pull motion from the orbit of the hub path to increase the maximum velocity of the clubhead during the downswing phase in men’s driver shot.

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