# THE RELATIONSHIP BETWEEN ANGULAR MOMENTUM OF BODY SEGMENT AND VELOCITY OF THE CLUBHEAD IN WOMEN'S DRIVER SHOT

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This study investigated the relationship between angular momentum of body segments and maximum clubhead velocity during the downswing phase in women's driver shots. Six female professional and eight female amateur golfers volunteered as subjects (age = 27.8 ± 15.1 yrs, 1.62 ± 0.05 m, 59.6 ± 7.6 kg). Motion was captured using a VICON motion capture system. Maximum clubhead velocity, angular velocity and angular momentum of the pelvis and thorax were calculated. Maximum clubhead velocity was 38.4 ± 1.9 m/s. Maximum angular momentum of pelvis and thorax about the Z-axis were 0.91 ± 0.16 $kgm^2/s$ and 1.48 ± 0.25 $kgm^2/s$, respectively. There was a significant correlation between thorax angular momentum about the Z-axis and maximum clubhead velocity. In order to gain higher clubhead velocity it is important to generate larger thorax angular momentum about the Z-axis and transfer momentum to the clubhead.

**KEYWORDS:** women's driver shot, clubhead velocity, angular momentum of thorax.

**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. Generally, it has been considered that 'Weight shift' and 'X-Factor' were important factors in increasing the ball velocity (Chu, Sell, & Lephart, 2010). The term X-Factor was introduced by Jim McLean in a 1992 Golf Magazine article titled "Widen the Gap" (McLean, 1992). It is used to describe the relative rotation of shoulders with respect to hips during the golf swing, specifically at the top of the backswing. There have been several studies reporting the transverse plane rotation of the pelvis and upper torso and their relationship with performance (Burden, Grimshaw, & Wallace, 1998; Cheetham, Martins, Mottram, & St Laurent, 2001; Egret, Vincent, Weber, Dujardin, & Chollet, 2003). These studies show aspects of proximal-to-distal sequencing (PDS) pattern as in most throwing and striking skills, whose goals are to maximize speed in the most distal segment of an open-link system (Putnam, 1993). However, this does not clarify the relationship between the angular momentum of body segments and maximum speed of the clubhead. The purpose of this study was to investigate the relationship between angulat momentum of body segments and maximum velocity of the clubhead during the downswing phase in women's driver shot.

**METHODS:** Six female professional and eight female amateur golfers were volunteered as subjects (age = 27.8 ± 15.1 yrs, 1.62 ± 0.05 m, 59.6 ± 7.6 kg). In this study, four of the professional golfers were golf instructors and the amateur golfers, aged from 12 to 24 years old were aiming to become professional golfers from. 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 performed 5 shots into a target net 5 m away. The fastest of the 5 shots of each participant was analyzed. The velocity of the clubhead was calculated. The Cardan angles of pelvis and thorax were also calculated. The X-factor was calculated relative to the Cardan angles of the thorax to the pelvis about the Z-axis at the top of backswing. The angle of the segments was filtered using a Butterworth filter with a cut off frequency of 10 Hz (Winter, 1990). Then angular velocity and angular momentum of pelvis and thorax about the Z-axis were calculated. The moment of inertia of body segments was estimated from the data of Ae (Ae, Tang, & Yokoi, 1992).

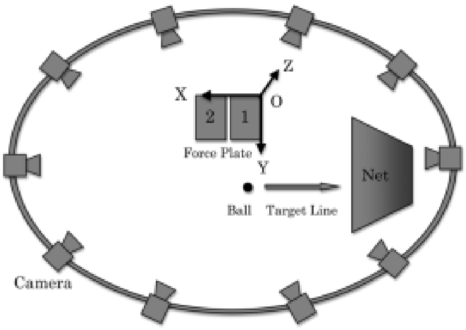


Figure 1: Experimental set-up.

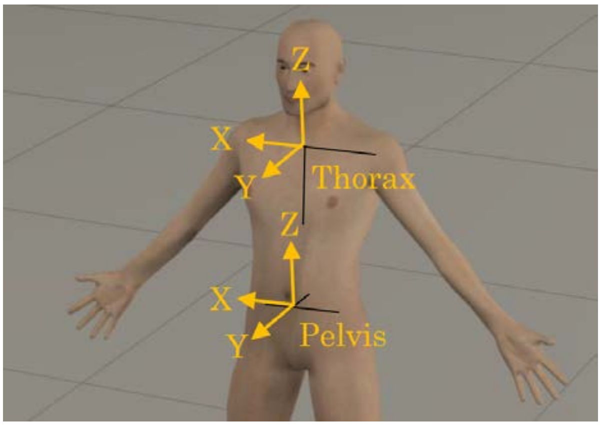


Figure 2: Coordinate system of the pelvis and thorax segments.

**RESULTS:** The maximum clubhead velocity was 38.4 ± 1.9 m/s just before impact. The X-factor of the top of backswing was 53.4 ± 10.0 deg. The maximum angular velocity of the pelvis and thorax about the Z-axis was 512.2 ± 80.5 deg/s and 709.2 ± 106.0 deg/s, respectively. The relationship between the maximum angular velocity of the pelvis and thorax about the Z-axis and maximum velocity of the clubhead during the downswing phase is shown in figure 3. There was no significant correlation between maximum angular velocity of the pelvis and thorax about the Z-axis and the maximum velocity of the clubhead during the downswing phase.

The maximum angular momentum of the pelvis and thorax about the Z-axis was 0.91 ± 0.16 $kgm^2/s$ and 1.48 ± 0.25 $kgm^2/s$, respectively. The relationship between the maximum angular momentum of the pelvis and thorax about the Z-axis and maximum velocity of the clubhead during the downswing phase is shown in figure 4. There was a significant correlation between the angular momentum of the thorax about the Z-axis and the maximum velocity of the clubhead ($p<0.001$). Although there was no significant correlation between the maximum angular momentum of the pelvis about the Z-axis and the maximum velocity of the clubhead.

Figure 5 shows an example of stacked area chart of angular momentum of pelvis and thorax about the Z-axis. The maximum angular momentum of pelvis about the Z-axis and thorax about the Z-axis were 0.101 ± 0.024 sec and 0.080 ± 0.009 sec before impact, respectively. Then total angular momentum was decreased. The relationship between decrease of angular momentum of pelvis and thorax about the Z-axis and maximum velocity of clubhead is shown in figure 6. There was a significant correlation between the decrease of the angular momentum of pelvis and thorax about the Z-axis and maximum velocity of the clubhead ($p<0.05$).

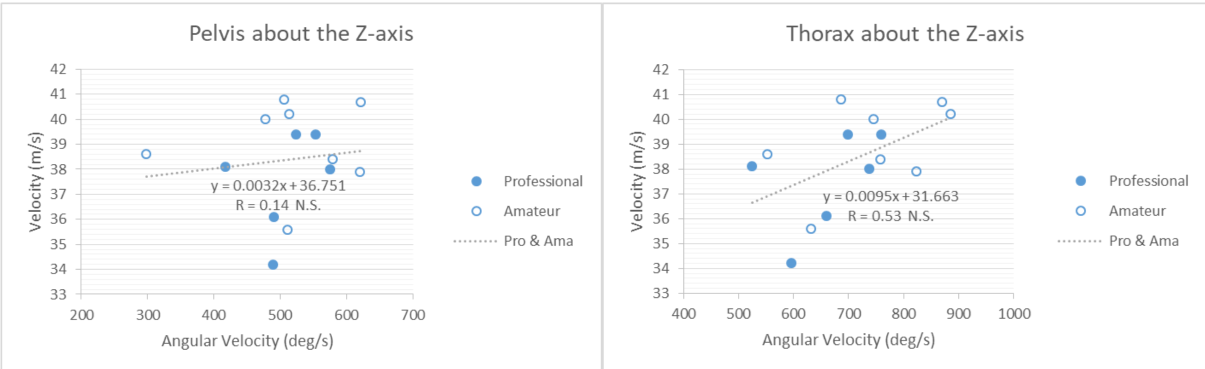


Figure 3: Relationship between the maximum angular velocity of the pelvis (left) and thorax (right) about the Z-axis and maximum velocity of the clubhead.

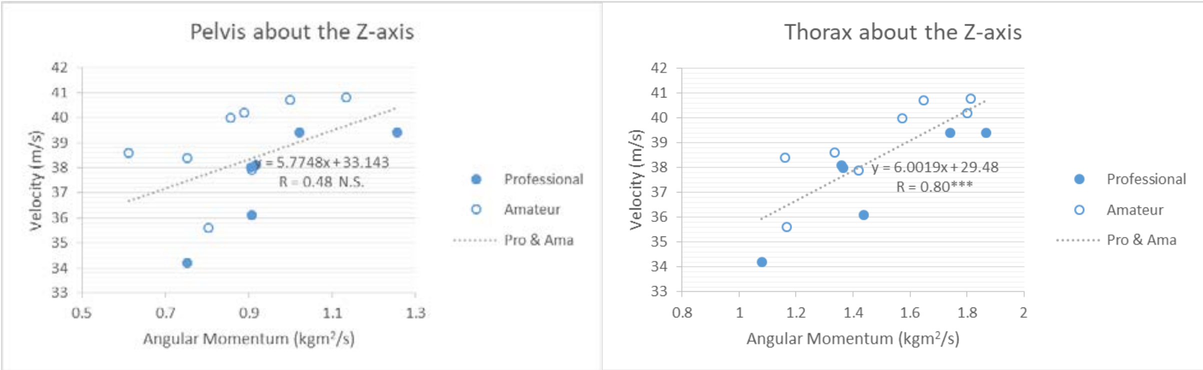


**Figure 4: Relationship between the maximum angular momentum of the pelvis (left) and thorax (right) about the Z-axis and maximum velocity of the clubhead.**

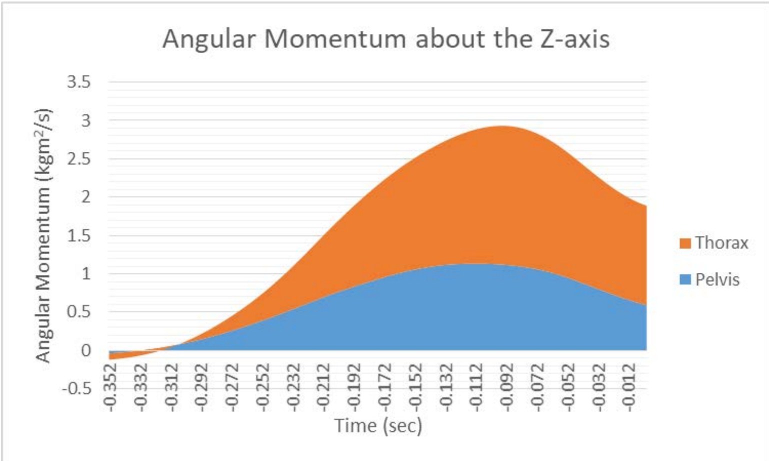


**Figure 5: An example of stacked area chart of angular momentum of pelvis and thorax about the Z-axis during the downswing phase.**

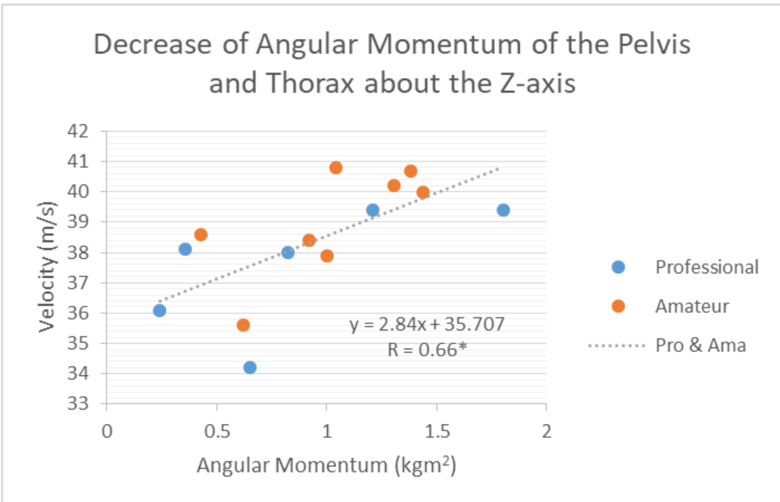


**Figure 6: Relationship between the decrease of angular momentum of the pelvis and thorax about the Z-axis and maximum velocity of the clubhead.**

**DISCUSSION:** This study analyzed the relationship between angular momentum of body segments and maximum velocity of the clubhead during the downswing phase in women's driver shot. The X-factor of the top of backswing was 53.4 ± 10.0 deg. Pelvic rotation reversed direction immediately before the beginning of the downswing, and was followed by a reversal of thorax rotation. Similarly, other studies have found that pelvic transition occurred before thorax transition, serving to increase the X-factor during the early part of the downswing. There was no significant correlation between the X-factor and maximum velocity of the clubhead. This result is different from a previous study (Meister et al., 2011). This difference was considered to be affected by the difference between sexes.

The maximum angular momentum of pelvis about the Z-axis and thorax about the Z-axis were 0.101 ± 0.024 sec and 0.080 ± 0.009 sec before impact, respectively. And then, angular momentum of pelvis and thorax about the Z-axis were decreased. At that time the velocity of the clubhead was rapidly increasing before impact. These movements utilize a kinetic chain to get higher angular velocity of distal segment.

Maximum angular momentum of pelvis and thorax about the Z-axis was observed about 0.1 sec before impact, then total angular momentum was decreased. A statistically significant correlation between the decrease of the angular momentum of pelvis and thorax about the Z-axis and maximum velocity of the clubhead was indicated ($p<0.05$). Therefore, these results suggest that the angular momentum was transferred from the thorax to the clubhead. In conclusion, in order to get higher clubhead velocity it is important to generate the larger angular momentum of thorax and transfer this to the clubhead.

**CONCLUSION:** This study analyzed the relationship between angulat momentum of body segments and maximum velocity of the clubhead during the downswing phase in women's driver shot. The maximum angular momentum of the pelvis and thorax about the Z-axis was 0.91 ± 0.16 $kgm^2/s$ and 1.48 ± 0.25 $kgm^2/s$, respectively. There was a significant correlation between the maximum angular momentum of the thorax about the Z-axis and the maximum velocity of the clubhead ($p<0.001$). There was a significant correlation between the decrease of angular momentum of the pelvis and thorax about the Z-axis and the maximum velocity of the clubhead ($p<0.05$). Therefore, these results suggest that the angular momentum was transferred from the thorax to the clubhead. In conclusion, in order to get higher clubhead velocity it is important to generate the larger angular momentum of thorax about the Z-axis and transfer this to the clubhead.

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