EXTERNAL MOMENT AROUND THE CENTRE OF MASS DURING GOLF SWING IN DIFFERENT WEIGHT TRANSFER STRATEGIES

Yoka Izumoto, Toshiyuki Kurihara, and Isaka Tadao

Faculty of Sport and Health Science, Ritsumeikan University, Ksatsu, Japan

The purpose of this study was to investigate the external moment around the centre of mass (COM) during the golf swing in golfers using different weight transfer strategies. The swing motions of twenty-one male golfers were captured by three-dimensional motion capture system. Ground reaction force of each foot was measured. External moments were calculated as the cross-product of the position vector from the COM to centre of pressure and ground reaction force vector. The golfers were divided into two groups whether the centre of pressure positioned front (n=8) or rear (n=13) relative to the COM at the impact. The external moments around the COM were not significantly different between two groups at the impact. It means that the golfers in different weight transfer strategies generate equivalents external moment by different strategies.

KEYWORDS: Swing style, External moment, Centre of pressure, Ground reaction force, Centre of mass, Weight transfer.

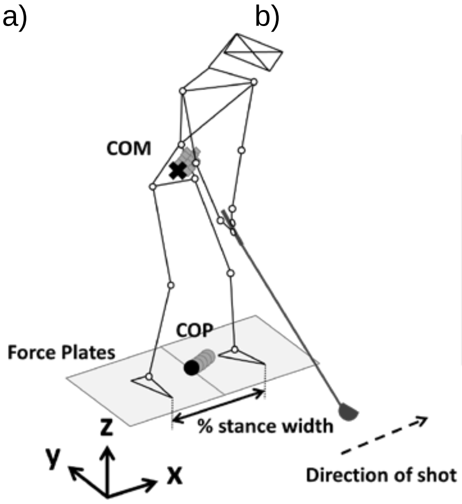
INTRODUCTION: The golf swing is a dynamic and complex total body motion that requires the golf players to hit a ball accurately over a variety of distances. As the required shot distance increases, the skilled golf players regulate the angular impulse consisted of the external moment around the whole-body centre of mass (COM) to achieve sufficient club head speed (McNitty-Gray et al. 2013; Peterson et al. 2016). Some previous studies determined that the whole-body rotation was associated with the ground reaction force (GRF) during the golf swing (Williams, 2004; McNitty-Gray et al. 2013; Peterson et al. 2016). In short, Unless the line of action of the GRF pass through the COM, the external moment would be generated. For getting successful shot, the players are desirable to get larger external moment around the COM generated by the GRF.
Some previous studies investigated the excursion pattern of the centre of pressure (COP), which was described as "weight transfer" during the golf swing (Ball and Best, 2007; Smith et al. 2017), instead of that of the COM. Ball and Best (2007) found that two types of excursion pattern of the COP in a medio-lateral direction within golf players; they classified the golf players as "Front foot style" (FS) and "Reverse style" (RS) groups. In the FS, the COP positioned at the front foot side, while in the RS, the COP positioned at the rear foot side at the ball impact (Smith et al. 2017). Although the definition of COM and that of COP are different, the COP is a point of application of combined GRF of each foot; therefore, the COP excursion could be related to the external moment around COM. We hypothesized that there would be a difference in the external moment around the COM between the FS and RS golf players. The purpose of this study was to investigate the external moments around the COM during the golf swing in golf players using two different weight transfer strategies.

METHODS: Twenty-one right-handed male varsity golf players (age, 20.2 ± 0.8 years; 1.72 ± 0.05 m; 67.3 ± 10.0 kg) participated in this study. They were experienced golfers (11.4 ± 3.5 years) and their golf performances were relatively high (best score 66.3 ± 3.4 strokes; average score during recent one month 75.9 ± 3.4 strokes). All players completed 10 full golf swings with their own drivers in the laboratory. They wore a pair of sport shoes and were asked to place each foot on two separate force plates with the usual stance. The GRF of each foot was measured at 1000Hz, and the COP was computed by combining the GRFs of both feet. Whole body and golf club kinematics during the golf swing were obtained using three-dimensional motion capture system at 250 Hz. A 15-body-segment-model of the whole body and the club head speed were calculated from the kinematics data, and position of the body's COM was calculated from the model as the weighted sum of the segmental COMs of 15 body segments (Ae et al. 1992). External moments around the COM were calculated as the cross-product of the position vector from the COM to COP and the GRF vector, and resultant forces was obtained for each foot using the GRF data. The X-axis of the laboratory reference frame was parallel to the direction of the target from the initial ball placement. The Y-axis was aligned with the direction from toe to heel of right-handed golfer at the address, and the Z-axis was vertical upward [Figure 1a].

The positions of the COP and the COM on the X-axis were normalized to the stance width between the rear foot (0%) and the front foot (100%). Relative position between the COP and the COM was computed as the difference to the normalized COM position from the normalized COP position (COP-COM%). The positive value of the X-axis direction means that the COP positioned on the front side of the COM (FS), and the negative value of the X-axis direction means that the COP positioned on the rear side of the COM (RS). The players were classified into the FS and RS groups by the COP-COM% at the impact. Eight golfers were classified as the FS strategy (FS group), and 13 were classified golfers as the RS strategy (RS group) [Figure 1b]. Swing time was normalized for the downswing phase, 0% is top of backswing and 100% is ball impact.

Between-group differences in the external moment at the impact in two groups were determined using the independent t-test. The phase of club hand speed less than 0.3 m/s (translation phase: the short time period of approximately 20% during the downswing) is important for translation angular momentum to achieve high club head speed (Zheng & Shan, 2013). Pearson's product-moment correlation coefficients were calculated to examine the relationship between the external moment at the translation phase and the club head speed within groups. The significant level was set at 0.05 %.

a) b)



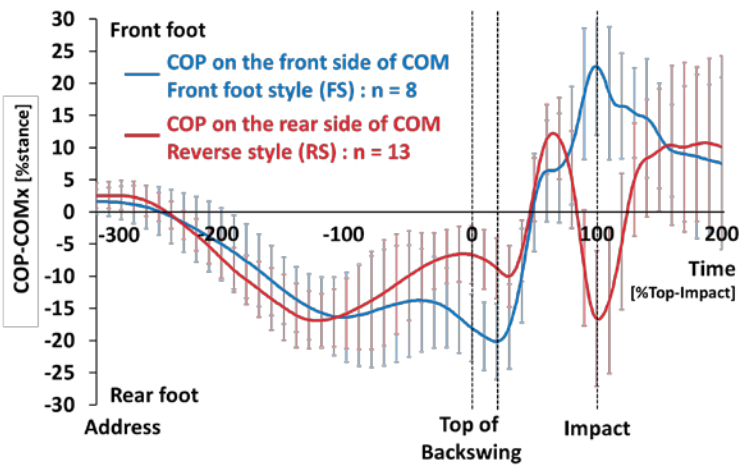


Figure 1: a) Experimental set-up for the study; b) The time curves of the relative position between the COP and the COM in X-axis for Front foot style (blue line) and Reverse style (red line) golf players. First vertical line indicates the top of backswing, second vertical line indicates the transition phase 20%downswing), third vertical line indicates the ball impact.

RESULTS: Figure 2a show the external moment patterns during the golf swing of the FS and RS groups. There was no significant difference between two groups in the external moment around the COM about the X-axis Y-axis, and Z-axis. Figure 2b shows the scatter plot between the external moment at the transition phase of the downswing and the club head speed of the FS and RS groups. For both the groups, the external moment around the COM about the Y-axis and Z-axis at the transition phase significantly correlated with the club head speed (r = - 0.49, 0.55). Figure 3 shows the resultant force patterns for the front foot and rear foot during the golf swing of the FS and RS groups. The resultant forces of the front foot and rear foot were significantly different between the FS and RS groups at the ball impact.

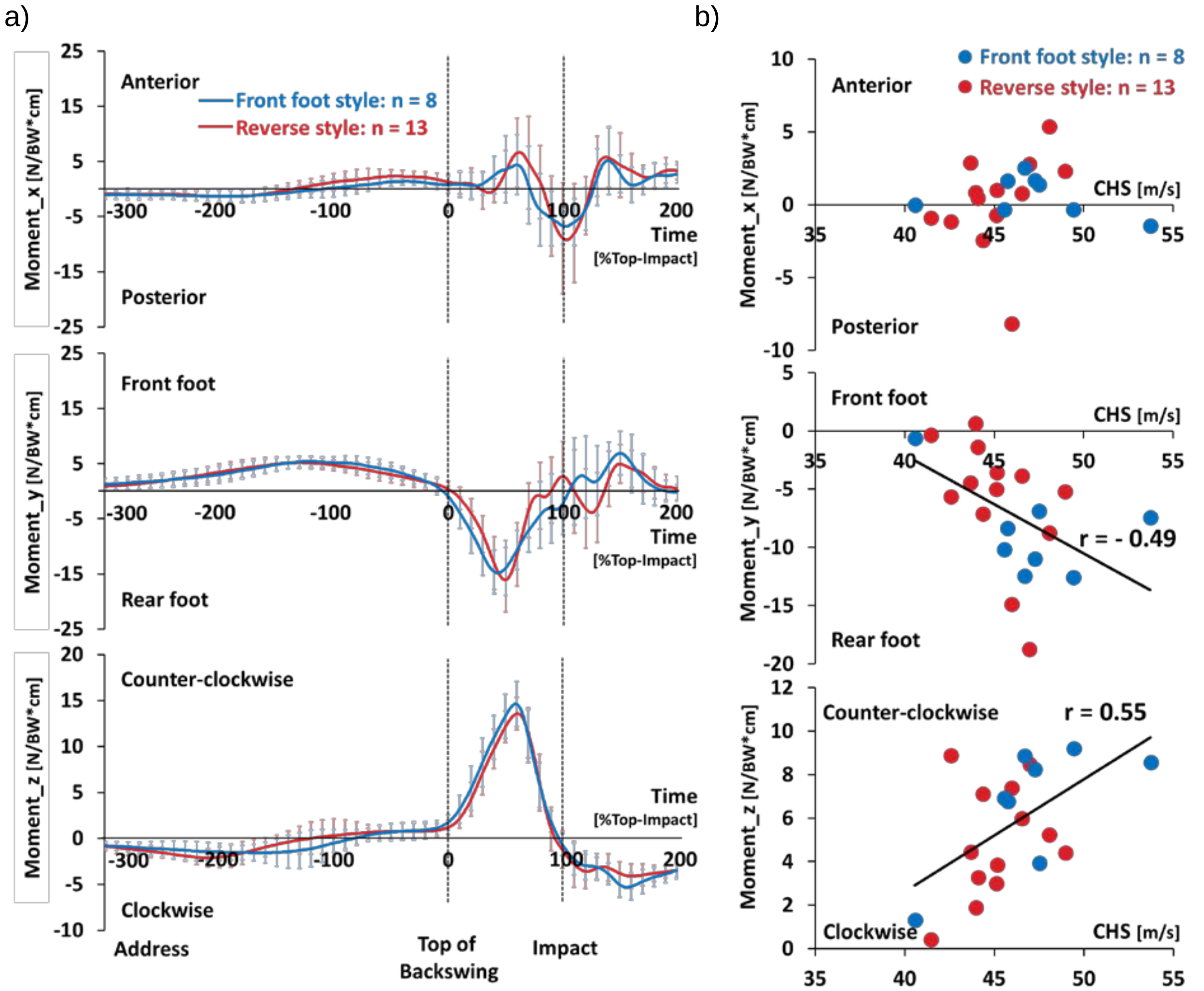


Figure 2: a) The external moments pattern during the golf swing for each of Front foot style (blue line) and Reverse style (red line) groups, b) Relationship between the external moments around the COM at the transition phase (20%downswing) and the club head speed (CHS) of the Front foot style (blue dots) and Reverse style (red dots) groups, x: about X-axis; y: about Y-axis; z: about Z-axis.

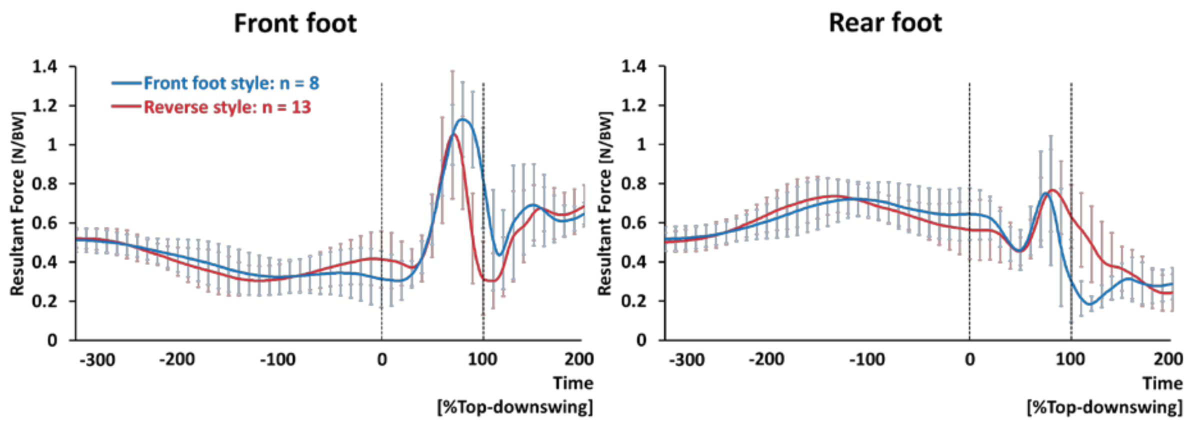


Figure 3: The resultant force patterns for the front foot and rear foot during the golf swing of the Front foot style (blue line) and Reverse style (red line) groups.

DISCUSSION: The external moments around the COM generated about all axes by the GRF did not differ between the FS and RS groups. This result means that a similar effect on the whole body rotation during the golf swing between the FS and RS group players: Especially in the downswing phase, the players accelerated their whole body rotation around swing direction (rotated for rear foot side in frontal plane and counter-clockwise in transverse plane). The resultant forces of both feet were significantly different between the FS and RS groups at the ball impact. Although the resultant force at the front foot was larger for the FS than the RS groups, and vice versa for that at the rear foot, the two groups generated the equivalent external moments. It means that the FS and RS players used different strategies to generate and control the equivalent external moment. The previous studies suggest that the skilled players used the strategies to obtain sufficient angular impulse regulating their external moment around the COM (McNitty-Gray et al. 2013; Peterson et al. 2016), but the results of this study indicate that there are two distinct different strategies on the two groups.
On the other hand, there are significant correlations between the external moment around the COM at the transition phase and the club head speed regardless of their styles (i.e. FS and RS). This result means that generating the larger external moment around the COM in the early downswing is important for both swing style players to get higher club head speed. The transition phase of downswing is one of the most important phase to accelerate the whole body rotation (Zheng & Shan, 2013), and in this study, the golf players, regardless of their styles, increased their COP and COM separation in this phase (Figure 1b). When the COP and COM separation increase, the moment arm length, which is the position vector from the COM to the COP perpendicular to the line of action of the GRF in horizontal and frontal plane, would be getting longer, then, the generating external moment getting larger in the swing direction. Peterson et al. (2016) indicated that some skilled golf players modify their moment arm to increase the angular impulse. By doing so, they regulate their external moment around the COM before the ball impact. It is inferred that both the group players would generate large external moment around the COM by increasing the separation between the COP and COM position in the early downswing, and then, they could accelerate their whole body rotation in the swing direction for getting the higher club head speed. Future research is required to investigate the swing motion kinematics and identify which strategies could generate the efficient external moment around the COM.

CONCLUSION: The external moments around the COM generated about all axes by the GRF did not differ between the FS and RS groups. However, the resultant forces of both feet were significantly different between the FS and RS groups at the ball impact. These suggest that the FS and RS players use different strategies to generate and control equivalent external moments.

REFERENCES

Ae, M., Tang, H., and Yokoi, T. (1992). Estimation of inertia properties of the body segments in Japanese athletes [in Japanese]. *Biomechanisms*, (11), 23-33.

Ball, K. A., & Best, R. J. (2007). Different centre of pressure patterns within the golf stroke II: group-based analysis. *Journal of Sports Sciences*, 25(7), 771-779.

McNitt-Gray, J. L., Munaretto, J., Zaferiou, A., Requejo, P. S., Flashner, H. (2013). Regulation of reaction forces during golf swing. *Sports Biomechanics,* 12(2), 121-131.

Peterson, T. J., Wilcox, R. R., McNitt-Gray, J. L. (2016). Angular Impulse and Balance Regulation During the Golf Swing. *Journal of Applied Biomechanics*, 32(4), 342-349.

Smith, A. C., Roberts, J. R., Kong, P. W., Forrester, S. E. (2016). Comparison of centre of gravity and centre of pressure patterns in the golf swing. *European Journal of Sports Sciences*, 17(2), 168-178.

Williams, K. R. (2004). Relationships between ground reaction forces during the golf swing and ability level. *The Engineering of Sport*, 5, 189-195.

Zhang, X., & Shan, G. (2014). Where do golf driver swings go wrong? Factors influencing driver swing consistency. *Scandinavian Journal of Medical Science in Sports*, 24(5), 749-757.