REGULATION OF ANGULAR IMPULSE DURING GOLF SWINGS WITH DIFFERENT CLUBS

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INTRODUCTION
Regulation of linear and angular momentum during well-practiced goal-directed movements involves control of the total body center of mass trajectory (CM) in relation to the reaction forces generated during contact with the environment\cite{1}. During the golf swing, the resultant horizontal component of the reaction force (RF\textsubscript{h}) at each foot creates a moment about a vertical axis passing through the CM that accelerates rotation of the body toward the target. Prior to the initiation of the downswing, this force couple applied to the body is created by the posterior directed RF\textsubscript{h} applied to the target foot (left foot in right handed players) and the anterior directed RF\textsubscript{h} applied to the rear foot (right foot)\cite{2}. Generation of linear momentum in the direction of the target has been associated with the “shift in weight” from the rear leg to the target leg during the downswing\cite{3,4}, all while maintaining the CM trajectory within the base of support. Temporal sequencing of RFs generated by the same player using different clubs (driver vs irons) has been reported to be consistent within player\cite{2}; However, magnitudes of the vertical and anterior posterior components of the target leg RF were reported to be higher than when using a driver as compared to an iron \cite{2}.

During competition, players are permitted to use a limited number of clubs that vary in mechanical properties (e.g. shaft stiffness, club length, clubface angle, mass distribution etc.). Sometimes, a player needs to place a ball at a distance that falls into the gap between two clubs and must decide whether to push the distance on one club (e.g. 7 iron) or reduce distance on the other (e.g. 6 iron). In this study, we used a within-subject design to determine if the target and rear foot RF\textsubscript{hs} and moments are modified when attempting to regulate ball distance using the

We hypothesized that the target and rear foot RF\textsubscript{h} magnitudes and corresponding moments about the CM orientation would differ when attempting to vary ball distance and that the orientation of the RF\textsubscript{h} in relation to pin at the time of force modulation would remain the same.

METHODS
Skilled golfers (n=12; handicap < 5) were asked to participate in accordance with the institutional review board for human subjects. Reaction forces at the artificial turf-plate interface were quantified during each swing using dual force plates (Kistler, 1200 HZ). Kinematics of the body during the golf swing was captured at 110 Hz using reflective markers (MATT, Motion Reality, Inc.). Ball contact was synchronized at the time of ball contact using a microphone signal sampled along with the force-time data. Each player performed the golf swing by placing one foot on each plate using their normal address and hit a golf ball toward a target (“pin”) located behind a net. Each player repeated the swing four times as they would normally (N) and then four times as if attempting to either increase (+) (driver, 6 iron; TaylorMade-adidas Golf) or decrease (-) the distance (6 iron) to “fill the gap” between their clubs. Moments generated by the target and rear leg RF\textsubscript{s} about the CM were calculated from the cross product of the position vector from the CM to the center of pressure of the rear and the target legs and the resultant horizontal reaction force (RF\textsubscript{h}) measured for each foot. Moments generated by each foot were used to determine within player differences in kinematics, RF and moment generation between clubs and across attempted distances (-,N,+).
RESULTS AND DISCUSSION
As expected, moments created about the anterior-posterior and mediolateral axes passing through the CM acted in opposition to each other; Whereas, the moments created by the RFh about the vertical axis summed together to create a resultant moment toward target (Figures 1, 2).

Figure 1. Target (green) and rear (red) foot reaction forces during the downswing for an exemplar player using a 6 Iron and a Driver.

Regulation of the moment generated by RFh about the CM was modulated primarily by increasing or decreasing the magnitude of the resultant horizontal reaction force (Figure 2). Each player elected to modify the reaction force between club and distance conditions, keeping the orientation of the RFh in during the period of force modulation the same within player (Figure 3).

Figure 2. Comparison of moments about the mediolateral (bottom), anterior posterior (top), and vertical axis (middle) axes within and between clubs for two players. Moment-time characteristics are player specific, modulation of the net moment (blue) magnitude occurs during the same interval and may involve contributions from both feet.

CONCLUSIONS
Subtle yet consistent regulation of angular impulse was observed within player across clubs and distances. These changes in control between task conditions were observed as deviations from the remarkably consistent [2] force-time characteristics of each foot under normal conditions. Regulation of angular impulse by amplification of the reaction force while maintaining player-specific orientation of the reaction force relative to the pin may prove advantageous from both a muscle coordination and performance point of view.

REFERENCES

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