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Contribution of vertical and horizontal components of ground reaction forces on global motor moment during a golf swing: a preliminary study

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1. Introduction

The swing is a crucial movement for golf performance. During their swing, golfers apply forces on the ground through their feet at the origin of the clubhead acceleration. Most of the studies that investigated ground reaction forces during a golf swing focused on the vertical component. However horizontal forces (mediolateral and anteroposterior components) were shown to be different between golfers and to play a role in the generation of the global moment creating the clubhead acceleration (McNitt-Gray et al. 2013).

The aim of this study was to evaluate the respective contribution of vertical and horizontal components of the ground reaction forces to the global motor moment generated during the swing.

2. Methods

2.1. Experimental setup

Three recreational (golf handicaps of 19.5, 12 and 7) and three professional golfers (professionals since 2 months, 5 years and 9 years) participated to this study. They were all right handed golfers. The protocol was approved by an ethical committee and each volunteer gave his written informed consent prior to the experiments.

Subjects performed 20 golf swings with their own driver club, in an indoor motion analysis laboratory. Each swing was tracked with a dedicated launch monitor (TrackMan 3, Trackman golf), measuring the ball flight and simulating its trajectory. Each volunteer was equipped by 88 reflective markers. Four additional markers were fixed on the club and two others laid on the ground, aligned with the ball and perpendicularly to the club linear velocity at the impact. 3D locations of the markers were recorded through a 12-cameras optoelectronic motion capture system (Vicon, Oxford Metrics, 200 Hz, Nexus software). Simultaneously ground reaction forces were recorded through two force plates (OR6, AMTI, 1200 Hz), covered with an artificial turf, one under each foot.

2.2. Data processing

Swing performance was defined from the carry distance. Two swings per volunteer were selected: these with the highest and the lowest carries.

Swings were divided into 3 phases: backswing, downswing and follow-through. In particular the downswing began at the top of the backswing when the clubhead speed reached a minimum and ended with the ball impact detected by the two markers aligned with the ball before impact. Finally, follow-through began directly after the downswing and finished when the club was horizontal.

The center of mass was computed with a multibody kinematics optimization technique with OpenSim software (Delp et al. 2007) and a dedicated fullbody model. The wrench of mechanical action of the ground under each foot was expressed on the estimated centre of mass as well as the contribution of each component on the global motor moment: vertical vs horizontal for right and left foot.

The positions of the three markers on the club shaft were used to determine the swing plane through a least squares method, taking into account markers location during the last 70% of the frames during the period between the beginning of the backswing and the end of the early follow-through.

The global motor moment and the contribution of each component were finally projected on the normal direction of the swing plane ($\vec{n}_{swing}$). The average motor moment (M_{av}) generated during the downswing was computed, according to Equation (1).
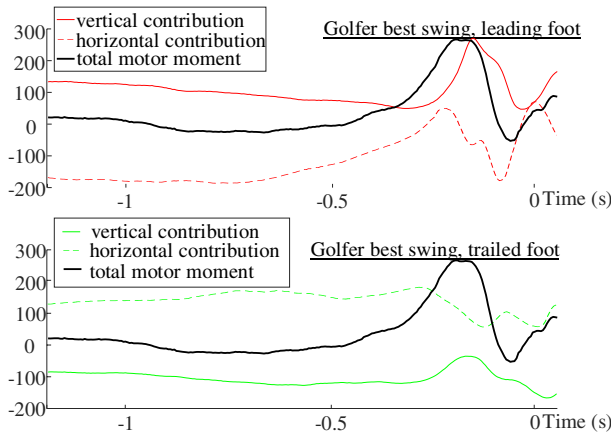
Figure 1. Contributions to global motor moment (Nm) of vertical and horizontal forces for both feet of one professional player for the leading (top) and trailed (bottom) foot. Time origin is set at impact.

$$M_{av} = \frac{1}{T_{downswing}} \int_{downswing} \vec{M}_G \cdot \vec{n}_{swing} \cdot dt \qquad (1)$$

where $T_{downswing}$ is the duration of the downswing, $\vec{M}_G$ is the global external moment expressed at the centre of mass, and $\vec{n}_{swing}$ is the unit vector which is normal to the swing plane.

3. Results and discussion

3.1. Swing characteristics

Downswing durations were 0.27 s on average (SD: 0.03 s, Table 1). This consistency is in accordance with previous results reported in the literature (Egret et al. 2003). All golfers described a relatively smooth plane during their downswings with an overall average of absolute distances between shaft markers and the computed plane of 7.7 mm (SD: 4.0 mm, Table 1). This consistency is in accordance with previous results (Kwon et al. 2012) but our results didn't show a clear tendency of professional golfers to better contain the club in a plane during the downswing phase.

3.2. Moment distribution

All golfers generated a peak of motor moment before impact and its magnitude is directly impacting carry.

This global motor moment is mainly generated by the vertical force of the leading foot but also by the horizontal force of the trailed foot for all the swings. The vertical force of the trailed foot and the horizontal force of the leading foot generate a negative moment or close to zero. These components are assumed to assist in stabilizing the golfer during the swing. The contributions of the local free moments generated under each foot are both negligible

Table 1. Swing characteristics: carry, club speed at impact (S_{club}), downswing duration (Down.), average and maximal motor moment during the downswing (M_{av} and M_{max}, respectively), and average absolute distance to swing plane (d_p).

Subject group	Amateurs mean (SD)	Amateurs min max	Professionals mean (SD)	Professionals min max
Carry (m)	173 (47)	108 240	248 (17)	225 271
S_{Club} (m/s)	42 (7)	35 51	50 (2)	48 52
Down. (s)	0.27 (0.02)	0.23 0.28	0.28 (0.03)	0.24 0.32
M_{av} (Nm/N)	0.16 (0.04)	0.10 0.21	0.17 (0.03)	0.14 0.23
M_{max} (Nm/N)	0.23 (0.06)	0.18 0.34	0.31 (0.04)	0.26 0.36
d_p (mm)	7.5 (4.3)	4.0 14.9	7.9 (4.0)	5.0 15.5

compared to other ones. Maximum values of global moment were positively correlated to clubhead speed at impact (cross correlation factor: $R^2 = 0.7$). However average motor moments were only slightly positively correlated to clubhead speed at impact ($R^2 = 0.3$).

4. Conclusions

Golfers with various skills were able to repeat the same swing with a high consistency both in phase durations and in the planarity of their movements. Both the peak and the average values of the global motor moment during the downswing were linked to swing performance. Obviously, the vertical forces were found to play a crucial role in the generation of this global motor moment. However, the horizontal component was also found decisive. Hence, measuring the 3 components of the ground reaction force instead of only the vertical one would be beneficial for analysing the golf swing.

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