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Analysis Of The Magnitude And Temporal Components of Ground Reaction Force During The Golf Swing: A Pilot Study

Aaron T. Trunt[1], Zadok J. K. Isaacs[2], and Lisa N. MacFadden[1,2]
[1] *Department of Biomedical Engineering, University of South Dakota, Sioux Falls, SD, United States*
[2] *Sanford Sports Science Institute, Sioux Falls, SD, United States*

Purpose: The golf swing is a multifaceted kinetic movement utilizing all planes of motion that has been found to not only be reliant on the overall production of forces but also the timing of when this force production occurs (Williams et al. 1983, Richards et al. 1985, Hume et al. 2005). The force exerted from the ground on the golfer, or ground reaction force (GRF), is a popular area of study in golf biomechanics. However, using GRF to accurately predict golf performance has been difficult due to the complexity of the swing. Previous research suggests that since the golf swing is happening in multiple planes, analyzing just one component of the ground reaction force produced by the golfer is not a sufficient way to predict performance (Bourgain et al. 2017). The purpose of this study was to assess the peak GRF produced in each direction during the golf swing as well as the timing of these forces and their respective relationship on club head speed.

Methods: This study was approved by the Sanford Institutional Review Board. Nineteen (6 females, 13 males) golfers (age 14-30) of varying skill levels from middle school to professional participated in this study. Subjects were asked to hit 10 balls with a driver and 10 balls with a 6-iron in the indoors Sanford Biomechanics Lab. Swing data was recorded using two high speed cameras (one positioned down the line and one positioned anterior to the golfer), a FlightScope Xi launch monitor, and two force plates (Bertec Co., Columbus Ohio) one placed under each foot of the golfer (Figure 1). Descriptive statistics and linear and quadratic models were used to assess the relationships between normalized magnitude, time, and direction of GRF and club speed. All statistical analysis was performed in MATLAB (Mathworks, Natick MA).

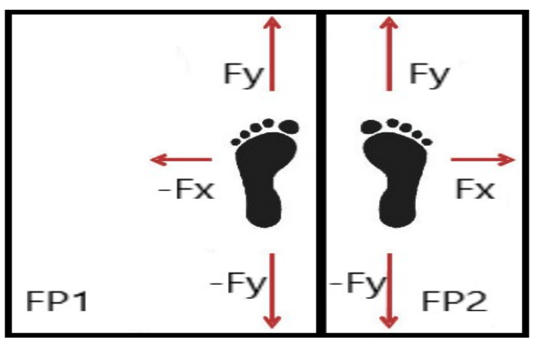

Figure 1: Force Plate Configuration

Results: Although most of the linear correlation models were significant on a 95% confidence interval as shown in Table 1, they had low R^2 values (<0.2) suggesting that linear relationships between peak GRF and timing of these peaks relative to one another as well as ball contact timing are not a sufficient way to predict club head speed. Quadratic models were almost always better predictors of performance (Table 2) when evaluating the same variables in the 6-iron. Interestingly, for each component of GRF F_x (medial / lateral), F_y (anterior / posterior) and F_z (vertical), it was often observed that performance was not always related to the same variable. For example, an increase in peak GRF for each foot or how close a golfer could produce peak GRF to time of contact were both important in the F_y direction however, in the F_x direction timing was not much of a factor and performance appeared to be more related to peak GRF on the lead foot alone. For driver swings, these same trends are not observed when looking at linear and quadratic relationships with no R^2>0.2 for any of the same variable/GRF combinations.

Discussion: These findings support that the golf swing is an intricate movement with many factors contributing to a successful swing. These results may demonstrate which variables are most important when assessing GRF for swing performance in each direction and corroborate preexisting studies that have found that both peak GRF and timing of these forces influences the golf swing. Though past studies have looked at the GRF of the golf swing, there's still much to be learned when analyzing GRF and the temporal and directional components that are crucial to a favorable golf swing. Given the low sample size of this study, the differences presented not only between different clubs but each GRF direction within the same club warrant further research and analysis.

Practical Application/ Clinical Relevance: The results of this study show that there is potentially a "sweet spot" regarding GRF and the timing of the forces the golfer is applying during the swing. For example, too little force in the anterior / posterior direction (F_y) in either foot can cause a potential under-rotation of the hips significantly affecting the performance of the golf swing. Likewise, too much force production may be detrimental. The same is true for timing of peak GRF under each foot which makes sense given that a golfer needs ample time to kinetically bring the force from the ground to the club. More research is necessary to determine if there is an optimal range for timing and magnitude for each GRF component to help maximize performance.

Table 1

Linear Model Fit Statistics for 6-Iron Variables and Club Speed

GRF Variables	Fz	Fy	Fx	Resultant
Front Foot GRF Peak	.0412	.18	.0228	Not Significant
Back Foot GRF Peak	.0796	.0306	.0923	.0559
Time Between Front and Back Foot GRF Peak	Not Significant	Not Significant	.144	Not Significant
Time Between Front Foot GRF Peak and Time of Contact	.136	.117	Not Significant	.126
Time Between Back Foot GRF Peak and Time of Contact	.072	.11	.157	.122

Note. All reported R^2 values were significant on a 95% confidence interval

Table 2

Quadratic Model Fit Statistics for 6-Iron Variables and Club Speed

GRF Variables	Fz	Fy	Fx	Resultant
Front Foot GRF Peak	.5599	.4724	.4066	.5620
Back Foot GRF Peak	.5520	.5483	.1973	.5500
Time Between Front and Back Foot GRF Peak	.3006	.0220	.0327	.3840
Time Between Front Foot GRF Peak and Time of Contact	.0336	.5899	Not Significant	.4575
Time Between Back Foot GRF Peak and Time of Contact	.3048	.5907	.0276	.5183

Note. All reported R^2 values were significant on a 95% confidence interval

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