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Ground reaction forces during the full driver shot of a Japanese male professional golfer: a case study

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Abstract

We examined the characteristics of ground reaction forces (GRFs) during the full driver shot of an individual Japanese male professional golfer. In addition to the Japanese male professional golfer, a male collegiate amateur golfer participated in this study. By comparing the GRFs during the backswing and downswing with two golfers, we found that the professional golfer exhibited a transfer of loading from the rear leg to the front leg during the downswing, resulting production of higher peak vertical GRF in the front leg (1.51 N/BW). This finding may provide valuable insights into the magnitude and timing of force for golfers seeking to increase the distance of driver shots in golf practice.

Key words; Golf swing, Ground reaction force, Driver

1. Introduction

Increasing driver shot distance is one of the major concerns of many golfers because an increased driver shot shortens the required distance of the second shot, making it easier to aim for and reach the pin. Transferring more energy to the ball is necessary for increasing shot distance[1, 2]. One of the components of clubhead momentum at impact is the linear velocity of the club head, and the sum of the segmental forces and the ground reaction forces (GRFs) are required to increase the linear velocity of the club head and its underlying angular velocity. Thus, in golf swing analysis, it is essential to understand how the feet of the golfer pushes the ground to generate the kinetic chain of the body and club and increase clubhead velocity.

In recent years, the cost of force plates and similar devices for measuring vertical GRF has been reduced; thus, obtaining biofeedback on force information in golf practice has become feasible[3]. Therefore, it is important to investigate GRFs during a golf swing. Previous studies have investigated the characteristics of the GRFs of skilled golfers[3–8] and the relationship between GRFs and ball speed or clubhead velocity[9, 10]. These studies revealed that the magnitude of the vertical

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GRF of the front leg on the downswing and the change in the vertical GRF from the rear leg to the front leg was large and rapid, respectively, but dependent on the ability of the golfer and the ball speed or clubhead velocity[3–10]. However, the detailed GRF changes that occur during a full driver shot have not been shown previously, although this information could help a skilled golfer obtain maximum shot distance. Indeed, if these changes were clarified, the results would provide insights into the magnitude and timing of the force required to increase driver shot distance during golf practice.

In the current study, the GRFs of a Japanese male professional golfer during a full driver shot were investigated. We hypothesized that the full driver shot of the professional golfer would exhibit an exceptionally large vertical GRF of the front leg during the downswing and a loading transfer from the rear leg to the front leg.

2. Methods

2.1 Participants

A Japanese male professional golfer (age: 35 years; height: 1.82 m; body mass: 90.3 kg) and a male collegiate golfer (age: 21 years; height: 1.69 m; body mass: 69.3 kg) participated in this study. The former was considered an average-level professional golfer who had yet to win a Japanese tour championship victory. Before the study, both participants were thoroughly briefed on the experimental procedures and safety protocols, and their written consent to participate was obtained.

2.2 Task and Procedure

The experimental task entailed executing a full shot using a driver to attain maximum distance. The participants were permitted to use their drivers. Before the trial, the participants engaged in a warm-up routine that included stretching and swinging. The test consisted of hitting a teed-up ball toward a golf target placed on a ball collection net 2 m away from the teeing ground. The participants rated their performance on a scale of 1 to 5 (5＝excellent). They continued to hit the ball until they achieved at least three successful shots rated 4 or 5. Between trials, they were allowed to rest adequately at their discretion to prevent fatigue.

2.3 Data Collection and Analysis

The experiment was conducted in an indoor experimental facility (Figure 1). For each trial, the three-dimensional (3D) coordinates of the golf club were measured using an optical 3D motion capture system (Vicon MX, Vicon, Oxford, UK; 12 cameras at 200 Hz) with reflective markers attached to two points: one at the clubhead and one at the grip end. The GRFs of the front and rear legs were measured using two force plates (9287, Kistler; operated at 1000 Hz). A global coordinate system was defined with the x-axis in the forward direction (anteroposterior), the y-axis in the direction from the tee to the target (mediolateral), and the z-axis in the vertically upward direction (vertical) based on the address posture. Only the one shot that was rated the highest by the

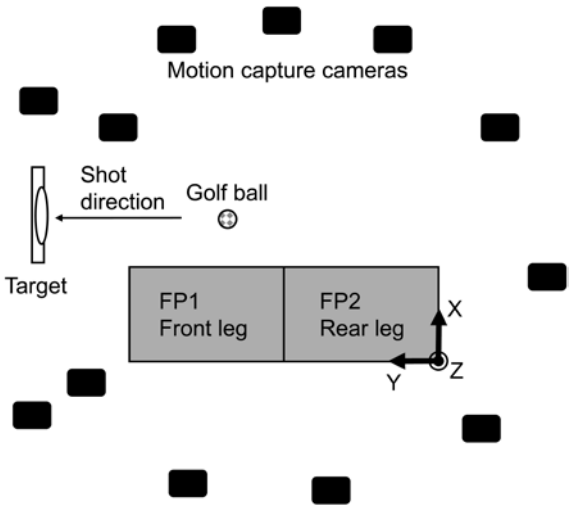

Figure 1. Experimental setup.

participants was analyzed.

The swing was divided into two phases: the backswing and the downswing. GRFs were normalized by participant body weight. Time-series data for vertical, lateral, and anterior–posterior GRFs were normalized to 100% for the backswing and downswing times, respectively, using a third-order spline function. The peak values of the anteroposterior, mediolateral, and vertical GRFs of the front and rear legs in the backswing and downswing were determined. The clubhead velocity was calculated by numerically differentiating the unfiltered clubhead 3D position data.

3. Results

Compared with the amateur golfer, the professional golfer exhibited a higher maximum clubhead velocity during a full driver shot (50.7 vs. 58.0 m/s, respectively).

Figure 2 illustrates the waveforms of the GRFs during the backswing and downswing of the professional and amateur golfer. Table 1 presents the peak GRFs of the two golfers. An anteroposterior GRF occurred in the backswing with the front leg behind the body and the rear leg in front of the body, and the orientations were reversed toward the end of the backswing. The magnitude of the anteroposterior GRF did not differ between the professional and amateur golfer in the downswing. The mediolateral GRF occurred in the opposite direction of the flight line for the front leg and in the direction of the flight line for the rear leg in the backswing. The magnitude of the mediolateral GRF was higher in the backswing for the rear leg of the professional golfer and smaller in the downswing for both legs of the professional golfer. The vertical GRF decreased for the front leg and increased for the rear leg from the beginning to the end of the backswing. Additionally, in the backswing, the professional golfer tended to have a greater vertical GRF of the front leg than the amateur golfer. In the downswing, the vertical GRF of the front leg increased, whereas that of the rear leg decreased. During the shot of the amateur golfer, the vertical GRF of

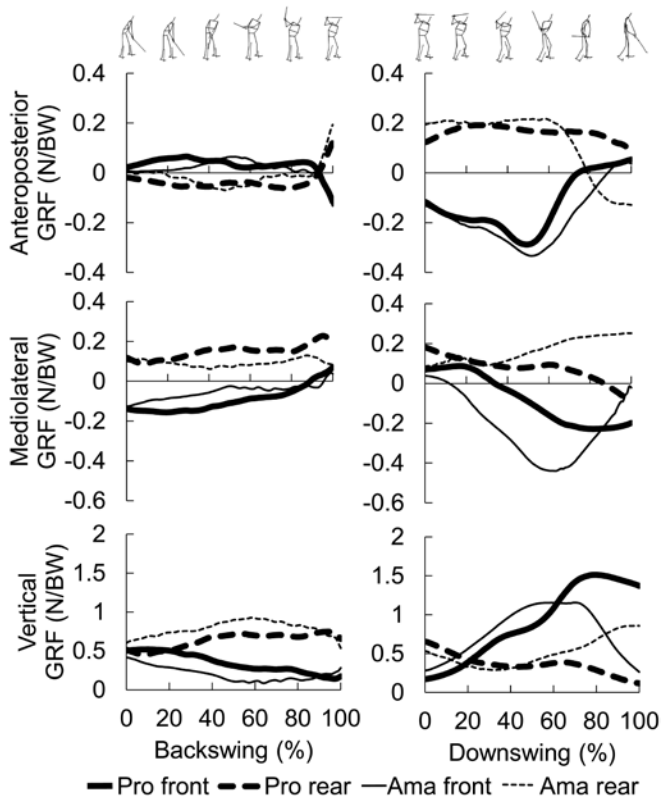

Figure 2. Waveforms of the ground reaction force during the backswing and downswing of a professional golfer and an amateur golfer.

Table 1. The peak ground reaction forces of the professional and amateur golfer.

				Backswing		Downswing	
				Pro	Ama	Pro	Ama
Front leg	Peak	AP GRF	N/BW	0.07	0.06	-0.29	-0.33
		ML GRF		-0.16	-0.13	-0.23	-0.44
		Vertical GRF		0.52	0.42	1.51	1.16
Rear leg	Peak	AP GRF	N/BW	-0.06	-0.07	0.19	0.22
		ML GRF		0.23	0.13	0.18	0.25
		Vertical GRF		0.75	0.93	0.65	0.86

AP: Anteroposterior. ML: Mediolateral.

the rear leg increased toward impact. Furthermore, the vertical GRF was higher for the front leg of the professional golfer in the downswing (Pro: 1.51 N/BW vs. Ama: 1.16 N/BW).

4. Discussion

The aim of this study was to determine the GRFs during a full driver shot in a Japanese male professional golfer. We found that the professional golfer exhibited high mediolateral GRFs for both legs and a high vertical GRF for the front leg in the backswing. Conversely, in the downswing, the

professional golfer exhibited a low mediolateral GRF and high vertical GRF for the front leg. Compared with the amateur golfer, the professional golfer exhibited a higher vertical GRF in the front leg during the downswing and greater load transfer from the rear leg to the front leg (Figure 3).

In the backswing, the professional golfer exhibited high mediolateral GRFs in both legs and a high vertical GRF in the front leg. The backswing is known to stretch the muscles and joints that produce force in the downswing[1]. A large weight shift is thought to lead to a shift in the center of mass of a golfer, making it difficult to control the swing. The professional golfer had a backswing with less weight transfer due to the increased mediolateral GRFs of both legs. Conversely, the large vertical load on the rear leg of the amateur golfer may have been detrimental to shot accuracy.

In the downswing, the vertical GRF of the professional golfer increased for the front leg and decreased for the rear leg, peaking at 1.51 N/BW in the front leg, which was higher than that of the amateur golfer (1.16 N/BW). Koenig et al.[5] previously found that the vertical force profile of low-handicap golfers is characterized by greater weight transfer at a faster rate on the downswing. Okuda et al.[8] found that skilled golfers exhibit faster horizontal pelvis rotation and faster weight transfer to the leading (front) foot during the downswing. The full driver shots of the professional golfer in the present study showed a similar pattern. Chu et al.[9] found that the large vertical GRFs of the leading foot during downswing acceleration and 40 ms prior to impact were major predictors of driven ball velocity. This can be considered from the perspective of parametric acceleration reported by Miura[11]. Parametric acceleration in a golf swing further increases clubhead velocity by pulling the grip upward near impact. Hence, in the present study, the clubhead velocity of the

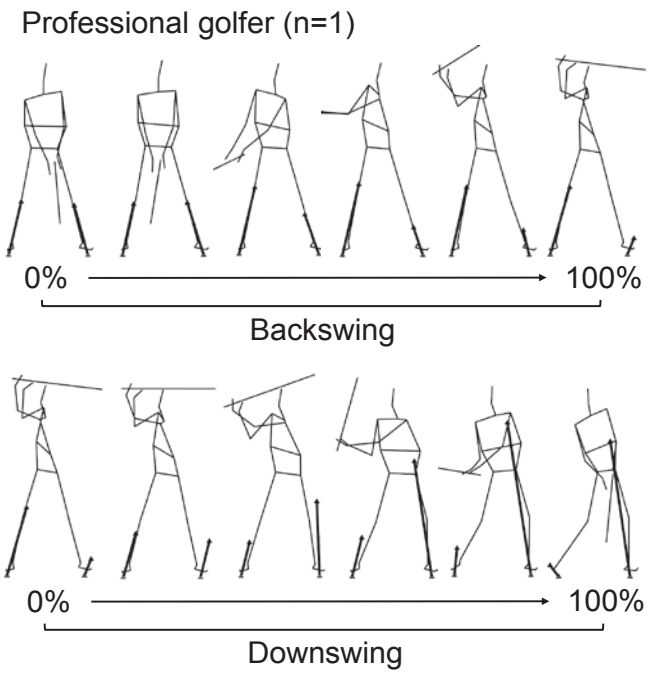

Figure 3. Stick pictures illustrating the full driver shot of the professional golfer. Bold arrows indicate GRF vectors.

professional golfer may have increased owing to the vertical acceleration of the body's center of mass due to the large vertical GRF of the front leg in the downswing. In contrast, the amateur golfer exhibited an increase in the vertical GRF of the rear leg toward impact; therefore, the amateur golfer may need to accelerate the clubhead more effectively. These findings indicate that the push action with the front leg in the downswing is essential to the quality of the shot.

In future studies, a wider range of professional and amateur golfers with different performance levels should be tested because weight transfer in a golf swing varies widely between individuals[12, 13]. In recent years, the GRF moment acting on the golf club system has attracted attention as an important parameter other than the magnitude of GRFs[10] and should be considered in future studies.

In summary, we examined the GRFs of a Japanese professional golfer and an amateur golfer during full driver shots, finding that the professional golfer exhibited a higher vertical GRF in the front leg during the downswing and greater load transfer from the rear leg to the front leg. These results provide insights into the magnitude and timing of the forces required to increase the distance of driver shots during golf practice.

References

1) Hume PA, Keogh J, Reid D: The role of biomechanics in maximising distance and accuracy of golf shots. Sports Medicine, 2005, 35: 429-449.
2) Hellström J: Competitive elite golf. Sports Medicine, 2009, 39: 723-741.
3) Queen RM, Butler RJ, Dai B, et al.: Difference in peak weight transfer and timing based on golf handicap. Journal of Strength & Conditioning Research, 2013, 27: 2481-2486.
4) Barrentine S, Fleisig G, Johnson H, et al.: Ground reaction forces and torques of professional and amateur golfers. In: Farrally MR, Cochran AJ, editors. Science and golf II. Proceedings of the 1994 World Scientific Congress of Golf. London: E & FN Spon, 1994, 33-39.
5) Koenig G, Tamres M, Mann R: The biomechanics of the shoe-ground interaction in golf. In: Farrally MR, Cochran AJ, editors. Science and golf II. Proceedings of the 1994 World Scientific Congress of Golf. London: E & FN Spon, 1994, 40-45.
6) Okuda I, Armstrong C, Tsunezumi H, et al.: Biomechanical analysis of professional golfer' s swing: Hidemichi Tanaka. In: Thain E, editor. Science and golf VI. Proceedings of the 2002 World Scientific Congress of Golf. London: E & FN Spon, 2002, 19-27.
7) Kawashima K, Meshizuka T, Takeshita S: A kinematic analysis of foot force exerted on the soles during the golf swing among skilled and unskilled golfers: In: Farrally MR, Cochran AJ, editors. Science and golf III. Proceedings of the 1998 World Scientific Congress of Golf. Champaign (IL): Human Kinetics, 1999, 40-54.
8) Okuda I, Gribble P, Armstrong C: Trunk rotation and weight transfer patterns between skilled and low skilled golfers. Journal of Sports Science & Medicine, 2010, 9: 127.
9) Chu Y, Sell TC, Lephart SM: The relationship between biomechanical variables and driving performance during the golf swing. Journal of Sports Sciences, 2010, 28: 1251-1259.
10) Han KH, Como C, Kim J, et al.: Effects of the golfer-ground interaction on clubhead speed in skilled male golfers. Sports Biomechanics, 2019, 18: 115-134.
11) Miura K: Parametric acceleration–the effect of inward pull of the golf club at impact stage. Sports Engineering, 2001, 4: 75-86.
12) Ball K, Best R: Different centre of pressure patterns within the golf stroke I: Cluster analysis. Journal of Sports Sciences, 2007, 25: 757-770.
13) Ball K, Best R: Different centre of pressure patterns within the golf stroke II: Group-based analysis. Journal of Sports Sciences, 2007, 25: 771-779.