WEIGHT TRANSFER CHANGES DURING GOLF SHOTS FROM DIFFERENT LIES

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The aim of the present study was to examine changes in weight transfer during golf shots from flat, uphill, and downhill lies. Twelve male amateur golfers with a mean handicap of 1.6 ± 2.4 hit a total of 30 golf shots from flat, downhill, and uphill lies. A computer assisted rehabilitation environment (CAREN) was used to collect 3D kinematics and kinetics and a Foresight GC2 launch monitor was used to measure performance outcomes (ball speed, launch angle, azimuth, side spin, and offline displacement). The mean position of the centre of pressure moved approximately 9.4% closer to the front foot for downhill lies and approximately 8.9% closer to the back foot for uphill lies. The speed of the ball was not significantly affected by the lie, but the distance the ball travelled was. An uphill lie encourages spin of the ball to the left, and may increase the risk of playing a hook shot.

KEY WORDS: slope, centre of pressure, performance.

INTRODUCTION: Golf coaching literature often stresses the importance of the correct weight transfer pattern throughout the golf swing (Leadbetter, 1993; Norman, 1995). A typical weight transfer sequence will begin with an even distribution between the feet at address (Leadbetter, 1993). The golfer's weight then moves towards the back foot during the back swing, before moving towards the front foot just before the start of the down swing. A rapid transfer of weight towards the front foot then occurs from the early stage of the downswing through to ball contact and follow-through (Fig. 1).

Past golf research has typically taken place in controlled laboratory conditions, where subjects are asked to hit shots from flat lies into nets during kinematic and kinetic data collection. These studies have provided useful insights into the mechanics and performance of the golf swing, and have shown that centre of pressure motion (weight shift) during the golf swing has strong correlations with the production of club head velocity (Ball et al., 2001; Wallace, Graham & Bleakley, 1990). However, golf courses are variable environments, where conditions can change from shot to shot, and a game of golf is more than likely to include uneven ground, requiring shots to be played off an uphill or downhill slope.

Popular coaching literature for playing off uneven lies (Leadbetter, 1993; Hunter, 2010) has been derived from playing and coaching experience. Advice from this literature suggests the golfer should set their body to be perpendicular to the slope (Hunter, 2010; Leadbetter, 1993) and adopt a stance that is wider than normal to increase stability (Hunter, 2010). A setup with the body perpendicular to the slope will result in more weight transferred to the lower foot, causing a general weight shift to the back foot during uphill lies and to the front foot during downhill lies. On the other hand, Leadbetter (1993) advises the golfer should counter the natural urge to sway down the slope by shifting weight to the back foot for downhill lies and to the front foot for uphill lies. In addition, Leadbetter (1993) advises the golfer to move the ball nearer the front foot for uphill lies and nearer the back foot for downhill lies whilst putting more emphasis on swinging the arms and less on turning the body to assist in maintaining balance.

Golf courses are designed to incorporate the lie of the land, using slopes to increase the difficulty of the required shots to make the course more challenging. One limitation of golf biomechanics research has been the laboratory setting, with studies usually limited to examining shots from a flat lie and not being able to consider these natural elements of the golf course. The aim of the present study was to examine changes in weight transfer and performance outcomes during golf shots from flat, uphill, and downhill lies.

METHODS: Twelve male amateur golfers (age: 26 ± 9 [mean ± SD] years, mass: 82 ± 7 kg, height: 1.83 ± 0.8 m) with a mean handicap of 1.6 ± 2.4 (range: -3 to 5) volunteered to

participate in the study. All golfers completed a health screening questionnaire and gave written informed consent for participation in the study that was approved by the university ethical advisory committee.

Procedure: Following a self-selected warm-up, golfers hit a total of 30 shots, with 10 shots from three different slope conditions (flat, uphill, and downhill), towards a point located in the middle of a net positioned two meters away. Golfers used their own six iron club and Titleist golf balls (DT Solo, Titleist, Massachusetts, USA). All shots were performed from an artificial grass mat positioned on top of the Stewart Platform of a CAREN system (Motek Medical, Amsterdam, Netherlands), which was used to create uphill and downhill slopes of five degrees.

Data Collection: Kinematic data were collected using 12 Bonita B10 cameras (Vicon, Oxford Metrics Group, UK) sampling at 250 Hz. A marker set consisting of 45 markers was used to track full body motion, the club modelled using retro-reflective tape placed at three points along the shaft and two markers placed on the heel and toe end of the club. The ball was modelled using retro-reflective tape on the surface of the ball and tracked using a Foresight GC2 launch monitor (Foresight Sports, US). Force data were collected using two 0.4 by 0.6 m strain gauge force plates (FP4060-07, Bertec Corporation, Ohio, USA) sampling at 1000 Hz and topped with two non-overlapping artificial grass mats. A further four markers were placed on the Stewart platform surface to track the position and orientation of the platform to correct errors this introduces into the force plate measures (Preuss and Fung, 2004).

Data Analysis: Centre of pressure in the direction of the shot was normalised as a percentage of the distance between the right and left foot centres (Ball and Best, 2007), with 0% representing the back foot (right) and 100% the front foot (left). Following the descriptions from Ball and Best (2007) eight events commonly used as coaching indicators were identified during the golf swing action (Table 1) so that centre of pressure position at these key times could be evaluated for each slopes condition.

Performance outcomes measured by the Foresight GC2 launch monitor include: the rate the ball leaves the club face (ball speed), the angle relative to the horizontal that the ball laves the club face (launch angle), direction the ball is travelling relative to the target line (azimuth), the direction and magnitude the ball spins (side spin), and the perpendicular distance the ball would land away from the target line (offline).

Table 1
Definition of golf swing events (taken from Ball and Best, 2007)

Event	Description	Label
Takeaway	First backward movement of the club	TA
Middle backswing	Club shaft parallel to horizontal plane	MB
Late backswing	Club shaft perpendicular to horizontal plane	LB
Top backswing	Instant before shaft begins downswing	TB
Early downswing	Club shaft perpendicular to horizontal plane	ED
Middle downswing	Club shaft parallel to horizontal plane	MD
Ball contact	Instant of club contact with ball	BC
Middle follow-through	Club shaft parallel to horizontal plane	MF

Statistical Analysis: Trials were combined to create a mean score for each subject under each condition (flat, uphill, downhill) before further analysis. Repeated measures ANOVA's were used to assess the differences in centre of pressure position and performance outcomes between downhill, flat, and uphill lies. Post hoc tests were made using multiple repeated measures *t*-Tests with a Bonferroni correction. All data were assessed for normality and sphericity by the one-sample Kolmogorov-Smirnov test and Mauchly's test of sphericity. A Greenhouse-Geisser correction was used for any data that was found to violate the assumption of sphericity. The significance level was set to 0.05.

RESULTS & DISCUSSION: A general shift in the position of the centre of pressure was found throughout the golf swing for all participants during uphill and downhill lies (Fig. 1). Repeated measures one-way ANOVA showed there was a significant difference ($p < 0.001$)

between the position of the centre of pressure at each swing event. Further comparisons revealed significant differences ($p < 0.001$) for all comparisons between conditions at each of these swing events. The mean position of the centre of pressure moved approximately 9.4% closer to the front foot for downhill lies and approximately 8.9% closer to the back foot for uphill lies. Results would indicate the golfers were following the advice from the coaching literature and attempting to remain perpendicular to the slope, which resulted in a transfer of weight down the slope towards the lower foot. The general pattern of the centre of pressure remains unchanged between the three different lies (Fig. 1), indicating the golfers were not attempting to shift their weight up the slope during the course of the golf swing as was suggested by Leadbetter (1993).

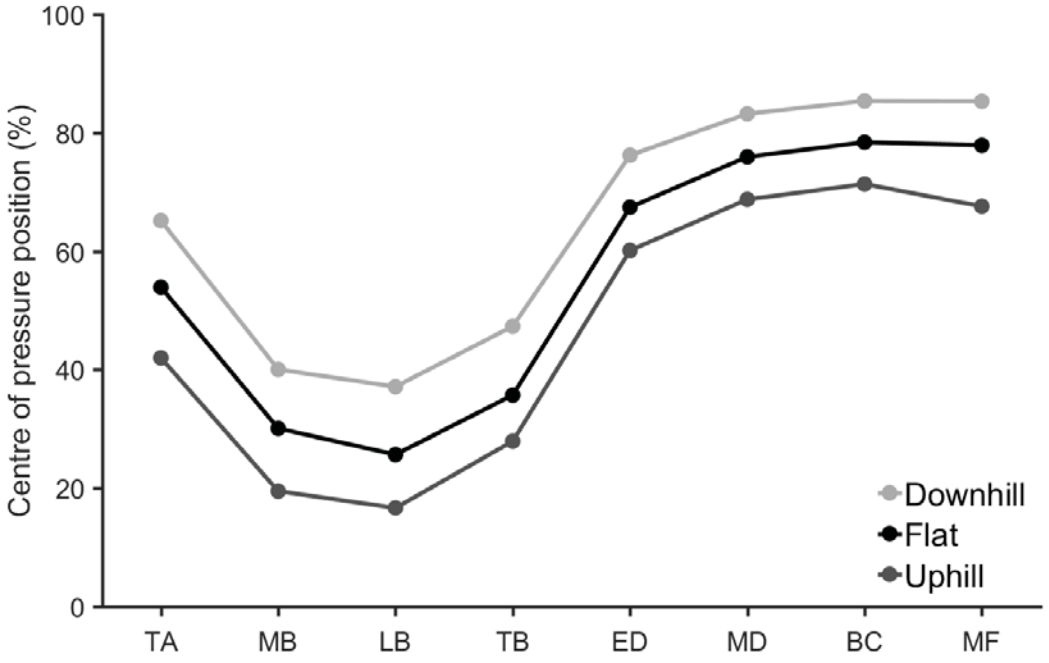

Figure 1: The position of centre of pressure between the back foot (0%) and front foot (100%) for downhill, flat, and uphill lies at each swing event (TA – takeaway; MB – middle backswing; LB – late backswing; TB – top backswing; ED – early downswing; MD – middle downswing; BC – ball contact; MF – middle follow-through).

Performance outcomes measured by the Foresight GC2 launch monitor show no significant difference in ball speeds or azimuth between the three lies (Table 2). However, there were significant differences between lies for launch angle, spin rate, and offline displacement. Results show, compared to a flat lie, there is a significant increase in launch angle for uphill lies, with a subsequent significant decrease for downhill lies. Significant changes in offline displacement and side spin show that, compared to a flat lie, shots from an uphill lie results in increased spin and movement of the ball towards the left. Conversely, downhill lies result more spin of the ball to the right and continued, but reduced, movement of the ball to the left. With very little change in azimuth between conditions, these results suggest the increased movement of the ball to the left for uphill shots is most likely due to the increased spin of the ball to the left, and the reduction of movement to the left for downhill lies is most likely due to increase spin of the ball to the right. Results indicate that the golfers assessed in the current study were playing draw shots to the left during an uphill lie and pull fade shots to the left for downhill lies. These findings of increase spin and movement of the ball to the left would suggest golfers are at an increased risk hooking the ball when playing shots from an uphill lie.

Table 2
Performance outcomes measured by the Foresight GC2 launch monitor for downhill, flat, and uphill lies.

	Ball speed (mph) Mean ± SD	Launch angle (°) Mean ± SD	Azimuth (°) Mean ± SD	Side spin (rpm) Mean ± SD	Offline (yards) Mean ± SD
Downhill (D)	122.2 ± 4.4	11.8 ± 1.4	-0.6 ± 2.1	122.6 ± 395.7	-0.5 ± 9.7
Flat (F)	123.4 ± 4.0	15.4 ± 1.5	0.0 ± 2.1	-125.1 ± 464.2	-2.9 ± 12.6
Uphill (U)	122.8 ± 3.6	19.1 ± 1.8	-0.3 ± 1.8	-386.6 ± 284.8	-8.4 ± 9.4
ANOVA:					
F stat	3.4	124.8	1.7	17.7	10.3
p value	> 0.05	< 0.001	> 0.05	< 0.001	< 0.001
t-Test:					
D vs. F	-	-7.9***	-	2.6	1.5
D vs. U	-	-12.5***	-	6.5***	4.4**
F vs. U	-	-12.3***	-	3.2*	2.9

Note: Significant *t*-Tests are indicated by *(p < 0.01), **(p < 0.005), ***(p < 0.001).

CONCLUSION: The aim of the present study was to examine changes in weight transfer and performance outcomes during golf shots from flat, uphill, and downhill lies. Results indicate the golfers were following the advice from the coaching literature and attempting to remain perpendicular to the slope, which resulted in a transfer of weight down the slope towards the lower foot. Performance outcomes indicate the speed of the ball is not significantly affected by the lie, but changes in the launch angle are likely to significantly alter the distance the ball travels. Golfers should be made aware that an uphill lie encourages spin of the ball to the left, and may put them at risk of playing a hook shot.

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