DIFFERENT WEIGHT TRANSFER PATTERNS IN GOLF

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The aim of this study was to determine if weight transfer swing styles exist in the golf swing. 40 golfers performed swings using a driver while standing on two force plates. Centre of pressure, used to indicate weight transfer, was normalized to foot position and quantified at eight swing events. Cluster analysis indicated that two major swing styles existed; a Front Foot style and a Reverse style. Both styles were similar from Takeaway to Early Downswing. Then, while the Front Foot group moved weight towards the front foot during the downswing, the Reverse group moved weight back towards the back foot. In the heel to toe direction, the Front Foot group hit from a mid-foot position, while the Reverse group hit with weight near the toes at ball contact. Cluster analysis is a useful tool for identifying different styles.

KEY WORDS: golf, weight transfer, swing styles, cluster analysis.

INTRODUCTION: The different swing styles of professional tour players are frequently discussed by commentators and coaches. The existence of swing styles has also been noted in the scientific literature. Neal (1998) used a golf coach to classify golfers into the translational style or the modern rotational style and found significant differences in weight transfer patterns between the styles. However, no study has attempted to objectively identify swing styles nor, more importantly, accounted for them when attempting to identify important performance parameters. Swing styles in a dataset can affect statistical analyses and may have contributed to the lack of significant findings in many studies examining weight transfer (e.g. Richards et al., 1985; Robinson, 1994). The aim of this study is to determine if different weight transfer styles exist in the golf swing, using cluster analysis to differentiate between styles.

METHOD: 40 male golfers (19 to 55 years old), ranging from professional golfers to high handicappers (Handicap = +2 to 26) and recreational players (minimum five games per year), performed 10 swings using a driver. Golfers adopted their preferred stance with each foot placed on separate AMTI force plates (Advanced Mechanical Technologies Inc, Massachusetts, USA), which were covered with synthetic grass. For each swing, centre of pressure (CP) displacement was calculated from force plate data sampled at 500 Hz using an AMLAB 16-bit ADC system (AMLAB Technologies, Sydney) and was smoothed using a 15 Hz Butterworth digital filter. For each trial, CP data was normalized to foot position. An overhead camera was positioned to capture foot position just before takeaway relative to the force plate coordinate system. The image was digitized using Peak Motus (Peak Performance Technologies, Englewood, Colorado). In the Y-axis (parallel to the line of shot) mid foot position of each foot (midway between the heel and toe in the Y-axis) was calculated and CPy displacement was expressed as a percentage (CPy%) of the distance between the back foot (0%) and front foot (100%). In the X-axis (perpendicular to the line of shot), the mid heel point (midway between the left and right heel in the X-axis) and the mid toe point (midway between the left and right toe in the x-axis) were calculated and CPx displacement was expressed as a percentage (CPx%) of the distance between the heel (0%) and the toe (100%). A 200 Hz Peak high-speed video camera was placed perpendicular to the line of shot and was used to identify eight swing events (table 1). For each trial horizontal clubhead speed immediately before ball contact and ball speed immediately after ball contact was measured using a ProV Swing Analyzer (Golftek Inc., Lewiston, Idaho). The mean value for all ten trials for CP and ProV data for each golfer was used in further analysis.

Table 1. Events in the golf swing and CP parameters quantified at each event.

	Event	Definition	Label	Parameters	
1	Takeaway	First backward movement of the club	TA	CPyTA	CPxTA
2	Mid Backswing	Club shaft parallel to the horizontal plane	MB	CPyMB	CPxMB
3	Late Backswing	Club shaft perpendicular to the horizontal plane when club is projected onto the YZ vertical plane	LB	CPyLB	CPxLB
4	Top Backswing	Instant before shaft begins downswing	TB	CPyTB	CPxTB
5	Early Downswing	Club shaft perpendicular to the horizontal plane when club is projected onto the YZ vertical plane	ED	CPyED	CPxED
6	Mid Downswing	Club shaft parallel to the horizontal plane	MD	CPyMD	CPxMD
7	Ball Contact	Instant of club contact with ball	BC	CPyBC	CPxBC
8	Mid Follow-through	Club shaft parallel to the horizontal plane	FT	CPyFT	CPxFT

To assess if different weight transfer styles exist, cluster analysis was performed using the Pearson's correlation similarity measure and the between-groups linkage clustering strategy. Initially, data was analysed hierarchically to see if large jumps existed in the agglomerative schedule (which indicate the presence of groups; Gower, 1975) and to identify potential cluster solutions (i.e. number of groups, or clusters, in the data). For each potential solution, cluster means were calculated and used as seeds in a non-hierarchical cluster process where each case (golfer) reclassified to the nearest cluster. Milligan and Sokol (1980) report finding cluster solutions more reliably using this two step process due to the elimination of nesting, where a case may be clustered with a group early in the hierarchical process but which may be better classified in another cluster in the final solution. The final solution considered optimal was based on the largest C-Index score (one of the strongest indicators of 30 tested by Milligan and Cooper, 1980). Validation of the cluster solution was performed using Point Biserial Correlation (significant score required), described by Milligan (1981) as a strong validation method, ANOVA to assess if clusters were significantly different (Hair *et al.*, 1995) and replication (Hodge and Petlichkoff, 2000), where three subsets of $N = 28$ golfers were randomly drawn from the group ($N = 40$) and reanalyzed.

RESULTS: The agglomerative schedule from hierarchical cluster analysis indicated the largest jump existed for the 2-cluster solution. However, moderately large jumps existed in the range of three to six clusters and so all were analysed non-hierarchically. Of these, the 2-cluster solution returned the largest C-Index. Clusters were validated by Point Biserial Correlation ($r_{pbi} = 0.48$, $p < 0.001$) and in replication analyses, where both patterns appeared in all analyses. Univariate ANOVA indicated that groups were significantly different at CPyMD ($F = 11.9$, $p < 0.001$; effect size, $\eta^2 = 0.29$) CPyBC ($F = 50.8$, $p < 0.001$; $\eta^2 = 0.64$), CPyFT ($F = 52.2$, $p < 0.001$; $\eta^2 = 0.66$), CPxBC ($F = 4.5$, $p = 0.04$; $\eta^2 = 0.14$) and CPxFT ($F = 10.4$, $p = 0.003$; $\eta^2 = 0.26$). The 2-cluster group means are represented in figure 1. For CPy%, both groups showed similar movement patterns in backswing, beginning at approximately 60% to the front foot and moving towards the back foot through MB, LB and TB. Also similar for both groups was a rapid forward movement of CPy% from TB to ED. From this point (CPyED = 63%) the Front Foot group continued to move towards the front foot (e.g. CPyBC = 76%), while group 1 (termed the Reverse group, $N = 12$) moved back towards the back foot (e.g. CPyBC = 43%). The CPx% profile from TA to ED was also similar for the two groups. Both groups moved only slightly during backswing, then moved rapidly forward towards the toes during the forward swing from TB (CPxTB ≅ 55%) to ED (CpxED ≅ 72%). The Reverse group then continued CP motion towards the toes (e.g. CPxBC = 76%) whereas the Front Foot group moved back towards the heel (e.g. CPxBC = 65%).

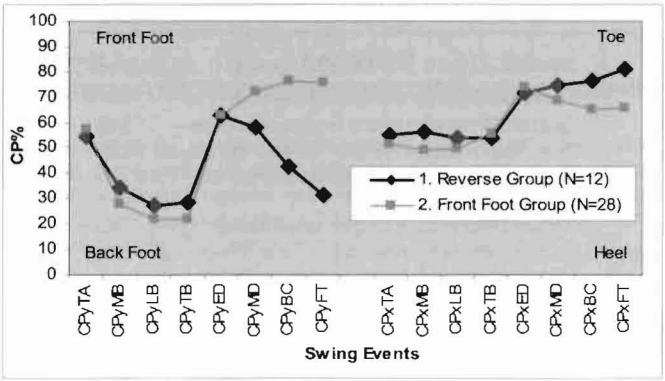

Figure 1. Mean CPy% and CPx% values for the 2-cluster solution.

Post-hoc analysis indicated that no difference existed between the groups for handicap, clubhead speed and ball speed (table 2). To compare the two groups found in this study with the two groups in the Neal (1998) study, the significantly different parameters from the Neal study were analysed; i.e. time of maximum CPy%, and the ratio between CPx and CPy range (table 2). Both were significantly different in this study too. The Front Foot group produced their maximum CPy% value significantly later in the swing (at $p<0.001$). The Front Foot group also produced significantly greater CPy movement relative to CPx movement (at $p<0.01$), as evident in the significant difference between groups for the CPx:CPy range ratio.

Table 2. Comparison of 2-cluster solution groups (Group 1 = Reverse, Group 2 = Front Foot).

	Handicap		Clubhead Velocity (m/s)		Ball Velocity (m/s)		Time of max CPy (% from TA-BC)		Ratio (m) CPx:CPy range	
Group	1	2	1	2	1	2	1	2	1	2
Mean	14	13	156	159	224	227	87	97	0.8	0.6
SD	12	7	17	13	27	19	9	4	0.2	0.2
F	0.10		0.33		0.20		29.6		7.66	
p	0.75		0.57		0.66		<0.001		0.01	
η^2	0.003		0.009		0.006		0.396		0.175	

DISCUSSION: Two major weight transfer swing styles were evident in the group of golfers analysed; a Front Foot group (N=28) and a Reverse group (N=12), named in relation to the CP motion between the feet (CPy%) after ED (see figure 1). No difference in handicap, clubhead velocity and ball velocity existed between groups. This suggests that both styles are used across the skill levels and that both can be used effectively. As well, of the six golfers who were professional or currently involved in professional tours, four were members of the Reverse group, further supporting this style as an efficient method of transferring weight. Comparison of this study's results with those of Neal (1998) suggests that similarities exist between this study's Front Foot group and Neal's translational group, and between this study's Reverse group and Neal's rotational group. Kinematic analyses are needed for this to be further substantiated. The weight transfer pattern exhibited by the Reverse group conflicts with the coaching literature on weight transfer. Leadbetter (1995) suggests that weight should move to the back foot during backswing and then to the front foot in downswing, and should be positioned on the front foot at

ball contact. The Reverse group shows a shift towards the back foot during downswing, hitting the ball when the weight is positioned closer to the back foot than the front foot (CPyBC = 43% for the Reverse group compared to CPyBC = 76% for the Front Foot group). This has implications for coaching. An awareness of the different weight transfer styles and the ability to classify a golfer into the most appropriate style would allow the coach to select more appropriate training cues. Further, different parameters will be important for the different groups. For example, in this study correlations between maximum CPy velocity and clubhead speed indicate that this parameter was important for Front Foot group (r = 0.45, p = 0.02) but not the Reverse group (r = 0.25, p = 0.48). While this relationship was significant when the group was treated as one (N = 40), the strength of association was reduced (r = 0.34, p = 0.02). Further, this relationship represents a type 1 error for the Reverse group, as it was not important when the group was treated separately.

CONCLUSION: Different weight transfer styles exist in the golf swing. In this study, two major styles were found; a Front Foot style and a Reverse style. Both styles showed similar weight transfer patterns in the backswing and during the initial stages of downswing. However, from early downswing onwards, the Front Foot group continued to move weight towards the front foot while the Reverse group moved weight towards the back foot. In the heel to toe direction, the Front Foot group positioned weight midway between the heel and toe at ball contact, while the Reverse group moved weight further towards the toe. Having two different swing styles has implications for coaches, as different cues and different techniques are relevant to each group. Cluster analysis is a useful method for identifying different styles that exist within a particular skill. More work is required to determine the important performance parameters for the Reverse and Front Foot groups. Future golf research needs to be conducted with Front Foot and Reverse groups included in the research design, where appropriate, in order to avoid making type I and type II statistical errors.

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