SWING AND LAUNCH PARAMETERS IN APPROACH-IRON SHOTS HIT WITH VARYING HEIGHT AND TRAJECTORY IN GOLF

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The first aim of this study was to determine whether relationships existed between variability of swing and launch parameters and variability in shot outcome for straight golf shots. The second aim was to determine whether differences existed for swing and launch parameters in shots intentionally played with varying height and trajectory. Elite (n=20) and high-level amateur (n=22) golfers hit; 1) five straight shots of normal height and 2) nine shots of differing height (low, normal, high) and trajectory (straight, draw, fade). Variability of club attack angle, face angle and ball spin axis was significantly associated ($p<0.05$) with variability in shot outcome. Further, several significant differences ($p<0.007$) for swing and launch parameters were found between shot type. Results from this study may assist coaches in providing real time feedback to their golfers.

KEY WORDS: elite, kinematics, variability, club, coaching, biomechanics.

INTRODUCTION: The golf swing is a complex motor skill and small changes in swing and launch parameters may lead to large changes in shot outcome. Although previous studies have examined the variability of swing and launch parameters of elite or high-level golfers (Kenny, Wallace & Otto, 2008; Bradshaw, Keogh, Hume, Maulder, Mortje, Marnewick, 2009; Betzler, Monk, Wallace & Otto, 2012), no study has reported variability of these characteristics with respect to their relative impact on variability in shot outcome. Additionally, in the game of golf players are required to hit shots of differing height and trajectory on demand. This is so the ball can be hit over, under or around obstacles as well as to account for environmental factors such as course terrain or wind conditions. Whilst previous research has described the swing and launch kinematics of maximal effort straight shots (Healy, Moran, Dickson, Hurley, Smeaton, O'Connor…Chockalingham, 2011; Betzler et al., 2012), no studies have investigated swing and launch parameters when golfers intentionally alter the height and trajectory of their shots. We recently developed the Nine-Ball Skills Test to assess the ability of high level amateur and elite golfers to hit approach shots at a target using a 5-iron with varying combinations of height (low, normal or high) and trajectory (straight, draw or fade) (Robertson, Burnett, Newton & Knight, 2012). For a right handed golfer a 'draw' shot involves the ball moving right to left whilst in the air, while a 'fade' shot involves moving the ball from left to right. There were two aims to this study. The first aim was to determine whether relationships existed between variability of swing and launch parameters and variability in shot outcome in straight shots of 'normal' height. The second aim was to determine whether differences existed for swing and launch parameters in shots played with varying height and trajectory.

METHODS: A total of 42 male golfers were recruited for this study. The sample consisted of elite (n=20) and high-level amateur (n=22) golfers. Inclusion criteria for the elite group were a) being a Professional Golfers Association (PGA) registered professional b) currently participating on either the Australasian PGA Tour or another internationally recognised professional golf tour and/or c) a current member of the Golf Australia Amateur National Squad. Players who held a Golf Australia handicap greater than 0.0 but equal to or less than 5.0 were included in the high-level amateur group. Ethical clearance to undertake the study was obtained from the Edith Cowan University Human Research Ethics Committee.

To measure swing and launch parameters, a Doppler radar launch monitor was used. The TrackMan (Interactive Sports Games, Denmark) is currently the device of choice on the US PGA Tour and has been used in recent golf biomechanics research (Betzler et al., 2012). For all shots played in this study, the launch monitor was placed 2.4 m - 3.6 m behind the golfer and was aligned with the middle of a central target area which was indicated by a flagstick.

After being informed of the testing protocol, participants performed a 10 min warm-up. Before undertaking the Nine Ball Skills Test, participants were requested to hit a straight shot of normal height using a 5-iron. The carry distance of this shot was measured then reported to the player. Participants were then asked to play a further four straight shots with the intention of "carrying" the ball to the same location as the first shot. The Percent Error Index (PEI) of the four repeated shots (with the initial shot as the target) was calculated as a measure of shot outcome. PEI is a commonly used indicator of shot outcome in golf and is the resultant of the "carry flat" and "side flat" distances normalised for the distance from which the ball is hit (Pelz, 1999). Bounce and roll distance of the ball was not considered in this study.

The protocol for the Nine-Ball Skills Test consisted of two parts (Robertson et al., 2012). Firstly, to adjust hitting distance for each player a normalisation protocol consisting of 15 shots (five straight, five draw and five fade shots) played using their typical swing was undertaken. As a result of this process, three individual target areas were constructed on the fairway for each participant. The draw and fade target areas were located 10 m left and right respectively of a central 10 m x 10 m area. A flagstick was placed in the middle of the area. Players then commenced a single round of the Nine-Ball Skills Test which consisted of nine shots of varying height (low, normal or high) and trajectory (straight, draw or fade). For each shot in the protocol, participants were instructed to align themselves with the central target area. For draw and fade shots, a 6º horizontal launch angle (based on a typical 150 m, 5-iron shot as reference) was implemented to prevent players from aiming directly at either the draw or fade target areas. Normal shot height was determined for each player based on mean values taken from the normalisation protocol. A ±10% window was used to determine whether each shot displayed 'normal' height in the test. Furthermore, low and high shots were considered to be <15% and >15% than the player's normal height and were scored accordingly. In the test protocol, all players performed shots in the following order; normal/straight, normal/draw, normal/fade, high/straight, high/draw, high/fade, low/straight, low/draw and low/fade. This was done to improve the test's implementation in the field. Following each shot, participants were provided with feedback regarding the maximum height, carry flat and side flat prior to performing their next shot. All wind conditions were monitored. Following testing, data related to the seven swing and launch parameters listed in Table 1 were exported to an Excel spreadsheet for further analysis. Negative values for face angle, club path and spin axis indicate orientation to the left when viewed in the transverse plane, whilst positive values indicated an orientation to the right. Both dynamic loft and attack angle refer to angles of the club at impact when viewed in the sagittal plane; negative attack angles refer to 'hitting down' on the ball whereas positive values indicate the ball is hit on the upswing. Dynamic loft refers to the actual loft of the club, plus or minus the attack angle at impact.

To assess the variability of each swing and launch parameter collected, median absolute differences (MAD) were calculated. To determine whether a significant relationship was present between the MAD of each swing and launch parameter and each player's variability of shot outcome (PEI MAD), Pearson's product moment correlations were used. Further, correlations between each parameter and absolute PEI values were also obtained. These analyses were only undertaken for the initial five shots played. To determine whether differences existed between means of each swing and launch parameter examined in the Nine Ball Skills Test, three-way ANOVA's with two within-subject variables (height and trajectory) and one between-subject variable (ability-level) were used. To reduce the likelihood of a Type I error the alpha level was adjusted to 0.007 (0.05 / 7 parameters) via the Bonferroni procedure. Post-hoc analyses using LSD tests for pairwise comparisons were undertaken where a significant main effect was found. SPSS V.20.0 for Windows (SPSS Inc, Seattle, WA, USA) was used for all statistical analyses.

RESULTS: Data relating to swing and launch parameters and PEI for the first phase of the protocol are presented in Table 1. Significant relationships were found between shot outcome variability (PEI MAD) and variability in; attack angle, face angle and spin axis. Further, these parameters showed significant relationships with shot outcome (average PEI). No significant differences were evident between elite and high-level amateur groups for all swing and launch parameters. Hence, results in Table 2 are reported with data pooled for group. There were several significant differences ($p<0.007$) evident between-shot and between-trajectory for swing and launch parameters. The differences between fade and draw shots, which have markedly different shot outcome left and right of the central target area, were of particular interest (Table 3). Some of these between shot differences were expected (i.e. club path and spin axis) however, significant differences ($p<0.007$) between-height and between-trajectory were also evident for parameters relating to the vertical axis (attack angle, dynamic loft & spin rate). Significant differences ($p<0.007$) were also observed between-trajectory for spin rate. When comparing the small magnitude of some of these differences measured during intentionally different shots (Table 3) to the MAD values for swing and launch parameters based upon repeat for straight shots of normal height (Table 1) it would appear that only small changes in swing and launch parameters are required to produce large differences in shot outcome. The relative importance of these parameters in creating such differences in shot outcome needs to be confirmed with further research.

Table 1: Mean (SD) values for percentage error index (PEI), PEI variability (measured as MAD) and swing and launch parameters in straight shots of normal height.

	Attack Angle (º)	Clubhead Speed (m/s)	Face Angle (º)	Dynamic Loft (º)	Club Path (º)	Spin Rate (rpm)	Spin Axis (º)	PEI (%)
Mean	-3.2	39.5	-0.4	16.8	0.8	6523	-2.3	6.5
(SD)	(1.3)	(3.0)	(3.1)	(4.5)	(4.1)	(746)	(8.6)	(4.2)
MAD	0.4*^	0.61	0.89*^	3.67	3.06	168	2.32*^	2.03

*significantly correlated with Mean PEI, ^significantly correlated with PEI variability (PEI MAD)

Table 2: Mean (SD) for swing and launch parameters for shots played in the Nine-Ball Skills Test.

	Normal/ Str.	Normal/ Draw	Normal /Fade	High/ Str.	High/ Draw	High/ Fade	Low/ Str.	Low/ Draw	Low/ Fade
Attack	-3.3	-3.3	-4.1	-3.5	-3.5	-3.7	-4.1	-3.5	-5.2
Angle (º)	(1.6)	(2.0)	(1.6)	(1.2)	(1.3)	(1.3)	(1.9)	(1.8)	(1.7)
CHS	40.1	40.2	40.2	40.7	40.6	40.5	40.6	40.2	39.5
(m/s)	(2.1)	(1.7)	(2.3)	(2.5)	(2.2)	(2.5)	(2.8)	(2.0)	(2.2)
Face	0.6	-1.2	0.3	-1.4	-1.3	-0.3	-1.3	-1.6	0.4
Angle (º)	(2.8)	(2.7)	(3.1)	(2.3)	(3.3)	(3.1)	(3.0)	(2.6)	(2.7)
Dynamic	17.2	15.7	18.2	18.9	18.0	18.2	15.4	14.7	14.5
Loft (º)	(2.3)	(2.4)	(2.1)	(2.6)	(2.3)	(6.0)	(3.0)	(2.7)	(2.6)
Club Path	-0.1	1.6	-0.1	-0.7	2.1	-2.0	0.9	2.8	-1.2
(º)	(5.4)	(4.8)	(5.3)	(4.8)	(5.3)	(3.7)	(4.9)	(5.4)	(5.0)
Spin Rate	6578	6233	7073	6862	6438	7040	6333	6165	6804
(rpm)	(959)	(776)	(886)	(903)	(738)	(868)	(750)	(767)	(886)
Spin Axis	0.9	-6.6	4.0	0.8	-4.8	4.5	-1.7	-6.7	3.1
(º)	(5.1)	(8.6)	(3.9)	(4.2)	(7.4)	(4.3)	(4.9)	(6.7)	(4.8)

DISCUSSION: Data reported this study may be useful to coaches, players and researchers alike. Firstly, our results suggest that players may be advised in attempting to reduce variability of face angle, attack angle and spin axis at impact in order to produce more consistent shot outcomes. Although variability of movement patterns in the golf swing has been recently investigated (Horan, Evans & Kavanagh, 2011; Betzler et al., 2012) there has been little work on variability of movement outcome. The launch monitor could be a valuable coaching tool as it may be used as a biofeedback device with golfers to increase consistency in practice situations. Additionally, undertaking future research that examines differing levels of contextual interference in skill tasks would allow for potential changes in variability to be

investigated when identical tasks are performed in random order, as opposed to the blocked format utilised in this study. A limitation of this study was the recruitment of small number of golfers (n=42). To more thoroughly investigate the traits of golfers of differing ability, an increased sample size may be required. In future, it is recommended that research is conducted to examine potential relationships between a) body kinematics b) swing and launch parameters and c) post-impact shot outcome.

Table 3: Summary of results for between-height and between-trajectory comparisons.

Parameter	Between-Height	Sig. findings and absolute difference in means (in brackets)	Between-Trajectory	Sig. findings and absolute difference in means (in brackets)
Attack Angle (º)	0.002	Low >High (0.7)	0.000	Draw <Fade (0.6) Straight <Fade (0.7)
Clubhead Speed (m/s)	0.240	No sig. results.	0.171	No sig. results.
Dynamic Loft (º)	0.000	Low <Normal (2.2) Normal <High (1.3) Low <High (3.5)	0.002	Draw <Straight (1.1)
Club Path (º)	0.156	No sig. results.	0.000	Draw >Straight (1.9) Draw >Fade (3.3) Straight <Fade (1.4)
Face Angle (º)	0.102	No sig. results.	0.001	Draw <Fade (1.5)
Spin Rate (rpm)	0.000	Low <High (346)	0.000	Draw <Straight (312) Draw <Fade (693) Straight >Fade (381)
Spin Axis (º)	0.289	No sig. results.	0.000	Draw <Straight (6) Draw <Fade (9.9) Straight <Fade (3.9)

CONCLUSIONS: There were two sets of conclusions in this study. Firstly, there was a significant association between variability of club attack angle, face angle and ball spin axis and variability (PEI MAD) in shot outcome. Secondly, this study has shown small, but significant differences in the swing and launch parameters between shot type. The differences between shot trajectory (straight, draw and fade) were of particular interest. Through identifying differences in swing and launch parameters and comparing these differences to variability in straight shots of normal height, this begins to investigate how small adjustments to these parameters may result in markedly different shot outcome. The results of this study may assist coaches in prioritising important elements of the swing as well as increasing movement consistency at ball impact.

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