ANALYSIS OF THE JOINT KINEMATICS OF THE 5 IRON GOLF SWING

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The purpose of this study was to identify the performance determining factors of the 5-iron golf swing. Joint kinematics were obtained from thirty male golfers using a twelve camera motion analysis system. Participants were divided into two groups, based on their ball launch speed (high vs. low). Those in the high ball speed group were deemed to be the more skillful group. Statistical analysis was used to identify the variables which differed significantly between the two groups, and could therefore be classified as the performance determining factors. The following factors were important to performance success: (i) the ability of the golfer to maintain a large X Factor angle and generate large X Factor angular velocity throughout the downswing, (ii) maintain the left arm as straight as possible throughout the swing, (iii) utilise greater movement of the hips in the direction of the target and a greater extension of the right hip during the downswing and (iv) greater flexion of both shoulders and less left shoulder internal rotation during the backswing.

KEY WORDS: golf, joint kinematics, 5 iron, ball launch speed.

INTRODUCTION:

Golf is played by 10-20% of the adult population in most countries (Thériault and Lachance 1998). The full golf swing using the iron clubs to strike the ball is a key element of success in golf. Therefore in order to help enhance golfing performance it is important to identify the "performance determining factors" of the full golf swing. Comparison of skilled and lesser skilled golfers' joint kinematics allows for the identification of these performance determining factors. Unfortunately, previous research has focused on the driver club despite the fact that either an equal or even a higher proportion of shots for maximum distance in the game of golf are taken with iron clubs. Only two studies (Budney and Bellow 1982, Cheetham et al. 2001) appear to have compared the kinematics of the golf swing of skilled and unskilled golfers using an iron club. There is a need therefore for research that focuses on golfing performance using the iron clubs. The aim of the present study is to identify the performance determining factors of the 5 iron golf swing through analysis of joint kinematics of skilled and lesser skilled golfers.

METHOD:

Participants: 30 male right handed golfers (34 ± 16 yrs.) were recruited for the study. Ethical approval was received from the Ethics Committee at Dublin City University. All participants were injury free at the time of the test. Participants underwent a familiarisation session in the laboratory prior to initiation of testing.

Data Collection: Forty one reflective spherical markers were placed on anatomical landmarks on the body. A 12 camera (250 Hz) VICON motion analysis system (VICON 512 M, Oxford Metrics Ltd, UK) was used to record the motion of the participant throughout the golf swing. The testing session consisted of a prescribed warm up, recording of fifteen golf swings and a participant selected cool down period. The prescribed warm up consisted of five minutes walking on a treadmill (2.5 km.h^{-1}) followed by 3mins of practice swings. The participants were instructed to 'hit the ball as hard as possible towards the target-line, with the aim to maximize both distance and accuracy, as if in a competitive situation'. The ball was hit from a tee on a Pro V swing analyser (Golftek Inc., USA) into a net located three metres from the swing analyser using their own 5 iron golf club.

Data Analysis: X factor (relative rotation of the shoulders with respect to the hips), shoulder, elbow, wrist, hip and knee angles and angular velocities were calculated using the 'golf' model (Vicon, Oxford Metrics Ltd, UK). The angle and angular velocity of each variable was obtained at each of the eight key events during the swing (Figure 1). Results for each participant's top three trials with regard to ball speed were averaged to create a representative trial of their best swing.

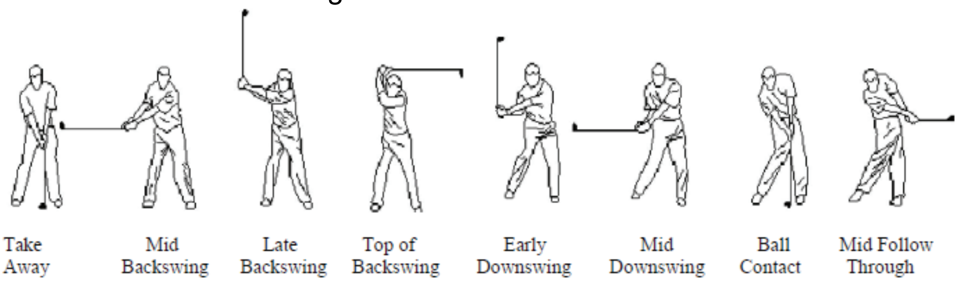

Figure 1: Key swing events. Adapted from Ball and Best (2007).

Statistical Analysis: Participants were divided into two groups, fifteen in each group, based on their ball launch speed [high ball speed (HBS) (52.9 ± 2.1 $m.s^{-1}$; handicap 0.1 ± 6.0) and low ball speed (LBS) (39.9 ± 5.2 $m.s^{-1}$; handicap 9.7 ± 7.5)]. Independent t-tests were used to assess differences between the groups ($\alpha = 0.05$).

RESULTS:

Due to the large number of variables analysed and subsequent significant differences found only those variables that showed differences across a minimum of three consecutive key events are presented. Results are presented for the X Factor angle (Table 1), left elbow flexion/extension angle (Table 2), right hip abduction/adduction angle (Table 3), right hip flexion/extension angle (Table 4), left and right shoulder flexion/extension angles (Table 5) and left shoulder internal/external rotation angles (Table 6). A relevant selection of angular velocity results are also included.

Table 1 Significant differences between groups (means ± standard deviations) for X Factor angle (°) and angular velocity (°.s^{-1})

X Factor	Group	Early Downswing	Mid Downswing	Ball Contact	Mid Follow Through
Angle (°)	HBS	-42.6 ± 6.3	-38.5 ± 6.1	-36.3 ± 5.3	-15.5 ± 11.2
	LBS	-35.1 ± 6.5	-30.4 ± 6.3	-26.8 ± 7.4	1.8 ± 13.3

Table 2 Significant differences between groups (means ± standard deviations) for left elbow flexion/extension angle (°) [flexion (+)/extension (-)]

Group	Mid Backswing	Late Backswing	Top of Backswing	Early Downswing
HBS	21.2 ± 5.8	26.5 ± 6.4	42.1 ± 10.6	32.2 ± 8.6
LBS	29.5 ± 11.3	36.2 ± 11.9	52.3 ± 9.8	43.6 ± 8.7

Table 3 Significant differences between groups (means ± standard deviations) for right hip abduction/adduction angle (°) [adduction (+)/abduction (-)]

Group	Early Downswing	Mid Downswing	Ball Contact
HBS	-16.97 ± 6.65	-25.35 ± 5.8	-27.14 ± 5.26
LBS	-3.97 ± 7.79	-14.19 ± 7.52	-18.53 ± 6.02

Table 4 Significant differences between groups (means ± standard deviations) for right hip flexion/extension angle (°) and angular velocity (°.s^{-1}) [flexion (+)/extension (-)]

Variable	Group	Early Downswing	Mid Downswing	Ball Contact	Mid Followthrough
angle (°)	HBS		18.9 ± 9.2	2.3 ± 9.4	-10.5 ± 9.5
	LBS		30.2 ± 13.9	14.5 ± 13.9	-0.2 ± 11.7
angular velocity	HBS	233.5 ± 87.3	443.2 ± 115.2		
(°.s^{-1})	LBS	77.1 ± 115.9	290.4 ± 106.7		

Table 5 Significant differences between groups (means ± standard deviations) for left and right shoulder flexion/extension angle (°) and angular velocity (°.s^{-1}) [flexion (+)/extension (-)]

Shoulder	Variable	Group	Mid Backswing	Late Backswing	Top of Backswing	Early Downswing
Left	angle (°)	HBS	46.9 ± 14.1	78.4 ± 12.3	114.1 ± 17	
		LBS	32.9 ± 15.6	55.8 ± 17.5	90.6 ± 19.8	
	angular velocity	HBS	138.2 ± 62.5	258.2 ± 131.9		494.5 ± 200.3
	(°.s^{-1})	LBS	91.3 ± 56.5	150.6 ± 85.4		36.3 ± 144.4
Right	angle (°)	HBS	40.6 ± 10.1	47.1 ± 9.8	57.3 ± 10.6	
		LBS	29.4 ± 8.9	33.9 ± 12.7	44.2 ± 15.9	
	angular velocity	HBS				206.0 ± 69.3
	(°.s^{-1})	LBS				114.9 ± 71.7

Table 6 Significant differences between groups (means ± standard deviations) for left shoulder internal/external rotation angle (°) and angular velocity (°.s^{-1}) [internal (-)/external (+)]

Variable	Group	Mid Backswing	Late Backswing	Top of Backswing	Early Downswing
angle (°)	HBS	-49.5 ± 17.6	-42.5 ± 15.1	-28.3 ± 20.9	
	LBS	-66.9 ± 15.2	-62.9 ± 14.6	-44.4 ± 17.7	
angular velocity	HBS				198.0 ± 238.2
(°.s^{-1})	LBS				36.3 ± 144.4

DISCUSSION:

Cheetham et al. (2001) was the only previous study found to examine the X Factor angle when using an iron club. Their study measured the X Factor at our fourth swing event, the top of the backswing. Similar to the present study they found no significant difference between their highly skilled and less skilled golfers. This finding for the 5 iron differs to recent research on the driver which has found significant differences for the X Factor at the top of the backswing between golfers of varying skill level (Myers et al. 2008, Zheng et al. 2008). In the present study the HBS group had a significantly greater X Factor angle at the events of early downswing (ED), mid downswing (MD) and ball contact (BC) (Table 1). They also exhibited a significantly greater X Factor angular velocity at mid downswing and ball contact (Table 1). These results suggest that the X Factor angle at the top of the backswing may not be the most important phase for the X Factor angle. It may be the ability of the golfer to maintain a larger X Factor angle and generate greater X Factor angular velocity throughout the downswing that contributes to producing higher ball speeds. No previous studies using an iron club have examined this. The HBS group kept their left elbow more extended than the LBS group at four consecutive events (from mid backswing to early downswing) (Table 2). The postulated benefit of this is the more extended a golfer keeps their arms the greater the velocity the club head is capable of generating since the club head travels through a longer arc in a given time and therefore moves faster (Broer 1973). The right hip was significantly more abducted for the HBS group (Table 3) resulting in them moving their hips more in the direction of the target during the downswing than the LBS group. The right hip for the HBS group was also more extended from mid downswing to mid follow through (Table 4); this is likely to aid in the faster transfer of weight to the front foot. Greater right hip flexion/extension angular velocity was evident for the HBS group at early and mid downswing

(Table 4). This ability to generate higher velocities early in the concentric phase (downswing) by the HBS group possibly contributed to their greater club head speed by employing a more enhanced utilisation of the stretch shortening cycle. The increased velocity of the hips early in the downswing also possibly indicates the HBS group's superior use of proximal to distal sequencing as they reached higher velocity of the proximal segment (hips) early in the concentric movement which possibly led to their higher velocity at the distal segment (club head). Results for left and right shoulder flexion/extension angles (Table 5) showed that the HBS group flexed their shoulders more during the backswing (at events mid backswing, late backswing and top of backswing), thereby utilising a greater range of motion in the backswing. This appears to have allowed the HBS group to produce greater extension angular velocity in both shoulders at early downswing. This is possibly due to effective utilisation of both the impulse-momentum relationship and utilisation of the stretch shortening cycle; with a greater angular velocity of the left shoulder by the HBS group evident at mid and late backswing. Higher velocities during the backswing increase eccentric loading, which increases the potential for enhancement in the concentric phase (downswing) through the stretch shortening cycle (Cavagna et al. 1968, Bosco et al. 1981), as evident by the significantly greater angular velocity during early downswing for the HBS group. The HBS group used less left shoulder internal rotation than the LBS group during the backswing (Table 6), despite producing a significantly greater angular velocity during early downswing. The smaller rotation may make use of an enhanced utilisation of the stretch shortening cycle (Moran and Wallace 2007).

CONCLUSION:

Clear performance determining factors are evident for swinging a 5 iron golf club to hit a ball as far and as accurately as possible. It is likely that maintaining a large X Factor angle and increasing X Factor angular velocity during the downswing could benefit golfers in increasing their ball launch velocity with the 5 iron club. In relation to the arms, greater ball velocity may be generated by maintaining the left arm as straight as possible throughout the swing, as this would increase the arc the club head travels through and therefore increase its velocity. A greater transfer of weight from the back to the front foot from early downswing through to ball contact brought about by greater movement of the hips in the direction of the target and a greater extension of the right hip allows greater force generation in the direction of the target, which can be transferred to the club to produce greater ball velocity. A greater flexion of both shoulders and less left shoulder internal rotation during the backswing in the direction of the target could also contribute to greater ball velocity generation.

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