AN EVALUATION OF THE KINEMATICS OF PUTTING TO ASSIST IN THE DEVELOPMENT OF FEEDBACK MECHANISM

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To develop a meaningful feedback mechanism it is essential to establish what elements of the motor skill require feedback and establish if differing levels of ability require feedback on the similar elements of the putting stroke. Volunteers (n=33) were grouped according to their putting ability. A kinematic analysis (200Hz) of each volunteers putting stroke was undertaken and this data was compared to the final resting position of the ball. Results demonstrated that yaw angle is an integral component of putting accuracy for all levels of golfers while club head velocity in the direction of the putt is vital for distance control. To ensure the appropriate development of a putting feedback mechanism the putting ability of the golfer must be known, to ensure that the specific feedback been given is suitable to the golfers needs.

KEY WORDS: golf, putting ability, kinematics.

INTRODUCTION:

Putting techniques may vary but the fundamentals of achieving the mechanical requirements remain the same (Cochran and Stobbs, 1968). The need for “squareness” or having the clubface orthogonal to the intended direction of the putt is a fundamental requirement in getting the ball to travel in the intended direction (Rosburg, 1963; Pelz, 2000; Werner and Greig, 2001; Brooks, 2002). The velocity of the club head dictates the speed with which the ball travels and in turn the distance the ball travels (Cochran and Stobbs, 1968; Hay, 1978; Langer and Saunders, 1987; Foston and Hiller, 1992; Lewis, 1994; Pelz, 2000). Acceleration at ball contact (Rosburg, 1963; Foston and Hiller, 1992; Newell *et al.*, 2004), striking the ball on the sweetspot of the putter face (Cochran and Stobbs, 1968; Pelz, 2000), putterface directed slightly upwards (Pelz, 2000; Werner and Greig, 2001) and amplitude of the downswing (Delay *et al.*, 1997; Fairweather and Button, 2002) have all been stated as factors in the golf ball travelling in the intended direction and at the required speed to go in the hole. The scientific process in establishing the importance of these aspects of the putting stroke is not always given. The literature does not specify if all aspects of the swing kinematics are as important nor if they apply for all levels of golfer. This study examines the relationship between each kinematic variable and performance and also establishes the relative importance of these variables with differing levels of putting ability.

METHOD:

Data Collection: Volunteers (n=33) were selected from responses to an e-mail to the college campus staff. A synthetic grass surface was laid flat on the laboratory floor. A mark was placed on the synthetic surface as the starting position of the ball; this was done to ensure a comparable putt for all volunteers. A white disc was placed on the surface 3m from the balls starting position. A disc was selected instead of a hole as the study attempted to establish performance outcomes not successful putts. The displacement of the ball would be effected by the ball dropping in the hole or direction of the shot altered by the ball hitting the side of the hole and deviating off course (lipping out). Each volunteer was asked to take 30 putts at the disc and treat the putt as if the disc was a hole and not a target to land the ball on. A six camera 200Hz motion analysis system (Evart 4.4, Motion Analysis Corporation, California) was set-up around the grass surface. The cameras were set-up to create a field of view measuring 3m*1.5m*5m (x*y*z, where y axis is up and z axis is a line joining the balls starting position and the centre of the white disc). Two retroreflective markers were placed on

the putter head and one on the shaft. These represented the putter movements and enabled the motion analysis software to gauge the kinematic parameters of the putting stroke. After each putt the final resting position of the ball was noted by replacing the ball with a retroreflective marker. Replacing the ball with the retroreflective marker ensured that the kinematic data and performance data were assessed using the same geometric coordinate system and improved the accuracy of the procedure.

Data Analysis: The volunteers were separated according to their putting ability as the handicap system can be an unreliable means of categorising golfers for single shot analysis (Fitzpatrick and Anderson, 2004). A mathematical derivation of putting ability can be seen in Table 1. The volunteers were segregated into three groups. Group 1 was designated to those volunteers that had a putting ability score less than highest ranked volunteer plus 1 standard deviation. Group 2 was designated according to those golfers that have putting ability scores greater than those of group 1 and less than the highest ranked volunteer plus 2 standard deviations. Group 3 was designated to those volunteers that have putting ability scores greater than those of group 2.

Table 1 Derivation of the formula to measure putting ability.

Performance Variable	Formula	Terms
Putting Ability	$\sqrt{(Consistency + Accuracy)}$	
Accuracy	$AccuracyX * AccuracyZ$	
Accuracy X	$\frac{\sum_{1}^{n} \lvert ADx \rvert}{n}$	*ADx* is the Axial Deviation and is the point at which the ball passes the x axis located at the centre of the disc. *n* is the number of putts taken.
Accuracy Z	$\frac{\sum_{1}^{n} R_d}{n}$	R_d is resultant ball displacement. *n* is the number of putts taken
Consistency	$ConsistencyX * ConsistencyZ$	
Consistency X	SD_{ADx}	Standard deviation of the ADx.
Consistency Z	SD_{Rd}	Standard deviation of R_d.

Seventeen kinematic variables of the putting stroke were measured and are listed and explained in Table 2. These kinematic variables were then compared to the performance outcomes AD_X and R_d (as explained in Table 1). This was undertaken to determine a relationship between the outcome of a putt and the kinematics of the putting stroke.

RESULTS:

A multiple regression analysis was performed on the data to compare the kinematic variables of the putting stroke to the final position of the ball. The regression equation, for each outcome and group, produced a high constant. Therefore the regression equation is used to rank the kinematic variables as opposed to creating a predictive equation. In figure 1, variables are ranked according to importance with the 3 highest ranked variables shaded.

DISCUSSION:

The intention of this study was to evaluate the relative importance of 17 kinematic variables to axial deviation in the x axis (ADx) and resultant displacement (Rd) of a golf putt. The

required elements of the putting stroke which affect accuracy (ADx) were ranked. As putting competency improves the key elements of putting stroke alter. Yaw is a crucial element of accuracy for all golfers and remains the most important element as golfers improve until they attain the level of proficiency of group 1 golfers. This substantiates the earlier mentioned literature on the importance of having the club face orthogonal to intended direction of the putt.

Table 2 Kinematic variables being analysed.

Variable	Explanation of variable
DSTIME	The duration of the downswing. From the top of upswing determined as the frame that downswing is initiated to ball strike.
DSX, DSY & DSZ	The total displacement of the downswing in the X, Y and Z direction.
VELX, VELY, VELZ & VELR	The velocity of the clubhead at ball contact in the X, Y & Z direction and resultant velocity.
ACCX, ACCY, ACCZ & ACCR	The acceleration of the clubhead at ball contact in the X, Y & Z direction and resultant acceleration.
YAW (Ψ)	The angle of the clubface against the XY plane.
PITCH (Φ)	The angle of the clubface against the ZX plane.
CLUBX & CLUBY	The position of the clubface in the X & Y direction. This endeavoured to establish how near the centre of the clubface the ball was hit (sweet spot).
AOA	Angle of Attack is the angle the clubhead was travelling along form the top of the back swing to ball contact.

Outcome	*Group*	*PITCH*	*YAW*	*CLUB X*	*CLUB Y*	*VELX*	*VELY*	*VELZ*	*VELR*	*ACCX*	*ACCY*	*ACCZ*	*ACCR*	*AOA*	*DSX*	*DSY*	*DSZ*	*DS TIME*
ADx	**1**		3	7	4		6							1		2	4	5
ADx	**2**		1			2						3						
ADx	**3**		1	3		2	6								7	5	4	
ADx	**All**		1	4	7	5	8							2	3		6	
Rd	**1**	12		10			5	1		8		11	4	9	6	2	3	7
Rd	**2**		8	3			4	1	2	7			5					6
Rd	**3**		4					1		3		5						2
Rd	**All**		4	6		3	2	1		10		8	9			7	5	

Figure 1 Ranking of kinematic variables against performance outcomes (ADx & Rd) according to putting ability (Group 1, 2 & 3).

Striking the ball on the sweetspot (CLUBX) and the velocity at which the club is coming across the ball (VELX) is an important component for group 3 golfers. Hitting the ball on the sweetspot diminishes in its relationship with putt outcome, as putting ability improves. This could be due to the fact that as putting ability improves the precision of the contact between the putter face and ball has progressed to a competent standard. As golfers putting ability progresses VELX no longer becomes a significant aspect of putting accuracy but the angle at which the clubhead approaches the ball (AOA) does. AOA is associated with VELX due to

the fact that unless the clubhead remains on the Zaxis (pendulum putting style) the clubhead will have a VELX component. The reason why VELX is no longer an integral part of putting accuracy for higher ranked putters may be because AOA is the angle between the top of the back swing and ball contact and VELX is the velocity in the x axis at ball contact. This may indicate that the more proficient putters have lined up there putts before ball contact while less capable putters may not have. To control distance the velocity of the clubhead in the direction of the putt (VELZ) is a critical element regardless of ability. It is interesting to note those golfers with the highest putting ability control this velocity with the amplitude of the down swing (DSY & DSZ). While previous research has shown the importance of the downswing (Delay *et al.*, 1997; Fairweather and Button, 2002) it has not been shown that this element is only used by those with advanced putting ability. It is also note worthy that pitch angle shows no significance with any outcome in putting and also the importance of acceleration may be exaggerated as it only appears in the top 3 factors of putting on 2 occasions.

CONCLUSION:

This study demonstrated that to develop a feedback tool for putting certain key elements must be gauged for all levels of golfers (YAW and VELZ). As ability progresses the key elements of putting change. As putting ability develops the amplitude of the downswing becomes a factor in controlling distance while AOA becomes an integral factor in accuracy. Therefore if a feedback mechanism is to be developed the putting ability of golfers must be first known before instruction on the key elements of the stroke can be given. This research has implications for any future work on putting feedback whether it is in design, research or coaching.

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