

KINEMATIC ANALYSIS OF GOLF PUTTING FOR EXPERT AND NOVICE GOLFERS

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The aim of this study was to identify some of the kinematic parameters used by expert golfers (≤ 6 handicap) to optimise putting efficiency and accuracy, and differentiate the putting techniques of elite and novice golfers. A 2D video analysis (50 Hz) was used to establish whether any differences existed for selected kinematic parameters of an 8 ft (2.46m) golf putt between expert ($n = 8$) and novice golfers ($n = 8$). Statistical analysis showed that 9 parameters from the 26 measured proved to be significantly different at the alpha level $P < 0.05$ between the expert and novice groups. This study assumed that expert golfers were more competent putters than novice golfers. Whilst this appears to be a reasonable claim it may not always be the case. Further improvements to the study could be to incorporate a scoring system to monitor the outcome of individual trials.

KEY WORDS: golf putting, kinematics, expert, novice

INTRODUCTION: In the modern-day game of golf, putting remains the key to shooting low scores, and the ability to hole putts can turn a good round into a great round. It has been reported that putting accounts for approximately 40 % of all golf shot played (Gwyn & Patch, 1993). However, golf practice does not seem to balance out the percentage between the golf swing and the golf putt. Virtually all golfers, regardless of their level of expertise suffer inconsistencies in putting performance due to the stroke being a complex and multi-faceted motor process. This is in part due to the fact that unlike golf driving, in which the need for maximum club head speed at impact largely determines the body actions that can be successfully employed, success in putting can be achieved using a variety of techniques (Cochran & Farrally, 1994). Despite this revealing statistic and the obvious importance of competent putting, much of the pedagogical literature is based on the observations and anecdotal evidence provided by top players and coaches. There is a general lack of published scientific research, and information regarding the kinematics of the putting stroke is scarce. Thus, the aim of this study was to identify some of the kinematic parameters used by expert golfers (≤ 6 handicap) to optimise putting efficiency and accuracy, and differentiate the putting techniques of elite and novice golfers.

METHODS: The study population consisted of right-handed amateur golfers from the University of Wales Institute, Cardiff (UWIC) and Celtic Manor Golf Club, Newport (CMGC). This population was separated into two groups of eight each, based on their playing ability; expert (EX) (age 23.3 ± 3.3 yrs, height 1.80 ± 0.1 m, handicap 2.3 ± 1.8 , experience 9.3 ± 2.1 yrs; mean \pm s) and novice (NO) (age 26.5 ± 3.2 yrs, height 1.7 ± 0.1 m, handicap 25 ± 2.6 , experience 1.5 ± 0.9 yrs; mean \pm s). The expert subjects had all represented UWIC in the British University championship and were practising regularly at the time of testing. Conversely, the novices from CMGC were recreational players who played on average once a week.

In order to carry out the study it was necessary to set up an artificial putting surface to allow for maximum control of potential external variables. A flat Astroturf surface was marked out with white tape (4m x 1.5m) to yield a straight putt with no break. At one end of the putting surface was a standard golf hole ($4\frac{1}{4}$ inches in diameter) and at the other end was a designated marker that ensured that the actual distance of each putt was equidistant, regardless of an individual's set-up technique.

Two-dimensional video analysis was used to capture three trials from each performer. A Panasonic F'15HS video camera was mounted upon Manfrotto 117 rigid stationary tripods 5 m away to capture a full field of performance. The camera was positioned perpendicular to the plane of performance, operating at 25 f/s with a 1/500 s shutter speed. Nine superficial markers were attached according to the guidelines suggested by Plagenhoef (1971) on the

vertex of the head and the joints of both the right and left upper extremities (glenohumeral, elbow, wrist and knee).

Before the commencement of testing each subject was allowed a considerable putting warm-up and trial period. Firstly, this was to ensure that familiarization occurred for the pace and nap of the putting surface, and secondly, each subject needed to become accustomed to the same ball and putter being used in the investigation. After the warm-up 2-D video data were collected for each subject performing a series of putts from a set distance of 2.46m (8 ft). It was explained that the purpose of the test was to determine an individual's normal putting technique for successful putts. The order of putts was randomized until all subjects had putted once, and then the procedure began again. This reduced the effect of muscular fatigue on the putting stroke and any learning effect that would result from continuous putting.

A single factor ANOVA was used to compare three trials by the same performer to identify any differences that may exist between selected variables across the trials. No significant differences ($P > 0.05$) between any of the variables were found, hence only the first trial per subject was used for data analysis. Co-ordinate digitizing was undertaken on an Acorn Archimedes 420/1 microcomputer equipped with the Kine System software (Bartlett and Bowen, 1993). Generalized cross-validated quintic spline that has been derived from a program by Woltring (1986) was then applied to remove random noise. Reconstruction was based on a user-defined 13-point model. To aid interpretation of results, key moments were introduced in the analysis to divide the stroke into five phases (Figure 1), as previously defined for qualitative analysis by Burden *et al.* (1998).

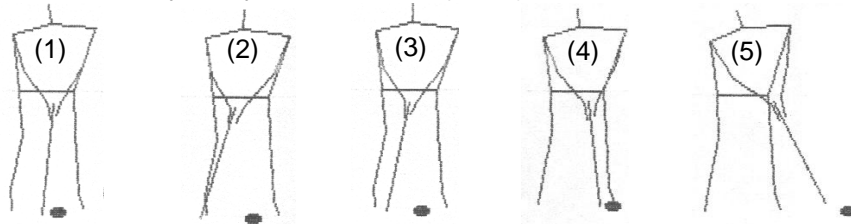


Figure 1- Typical stick figure sequences at five instants of the golf putt where kinematic parameters were measured. Ball address (1), Back swing (2), Forward swing (3), Ball impact (4) and Follow-through (5).

The following parameters were calculated: ball position, stance width and wrist positioning at ball address (*BA*), and the putter-head horizontal and vertical displacement, subject's head movement - horizontal and vertical displacement, timing of the back swing (*BS*), forward swing (*FS*), follow through (*FT*) and total putt time, angular displacement of the right and left elbow and also the angle formed by a line joining the left elbow to left wrist and putter shaft, maximum horizontal linear velocity and time it occurs, at *BS*, *FS* and *FT*.

Digitising reliability. Reliability and objectivity of the digitising process was established by repeated digitising of one sequence at the same sampling frequency with an intervening period of 48 h. The limits of agreement method (Bland and Altman, 1986) was used to compare these repeated digitised sequences and produced values for the angular displacement of the left elbow (*LE*) and the horizontal displacement of the putter head (*PH*) based on the equation $\delta \pm 1.96 \sigma$, where δ = mean of differences between repeated digitised sequences and σ = standard deviation of these differences, as the heteroscedasticity correlation was close to zero. Given these results (Table 1) it was concluded that the digitised data were reliable and objective.

RESULTS AND DISCUSSION: Statistical analysis showed that 9 parameters from the 26 measured proved to be significantly different between expert and novice players at the 95% level of confidence (Table 2).

In both groups the ball was positioned in the front third of the stance. This was not entirely expected but was probably due to the fact that modern coaches (Faldo, 1994; Pelz, 1995) are proponents of the technique of playing the ball opposite or slightly behind the left heel.

The advantage of this technique is that the ball will be contacted on a slight upstroke thus ensuring topspin and reducing the likelihood of the ball jumping at impact (Foston, 1992). The present study's data for hand positioning confirmed a significant difference ($P < 0.05$). It has been agreed previously that forward hand positioning locks the wrists into a firmer position, minimizing wrist involvement and ensuring that the individual putts with the larger muscles of the shoulders (Leadbetter, 1997).

Table 1 Limits of Agreement for the Reliability and Objectivity

Variable	Reliability			Objectivity		
	$m \pm s$	Low	High	$m \pm s$	Low	High
LE ($^{\circ}$)	-0.563 \pm 2.473	-3.036	1.91	-0.348 \pm 2.389	-2.737	2.041
PH (m)	-0.005 \pm 0.008	-0.013	0.003	-0.0009 \pm 0.004	-0.005	0.003

Table 2 A Summary of the Comparison between Expert and Novice Golfers (mean \pm s)

Variable	Expert	Novice
Left wrist to putter head (m)	0.08 \pm 0.03	0.004 \pm 0.06
Putter head displacement from BA to BS (m)	0.21 \pm 0.03	0.034 \pm 0.04
Horizontal displacement change from BA to BS (m)	0.02 \pm 0.01	0.03 \pm 0.009
Horizontal displacement change from BS to BI (m)	0.009 \pm 0.008	0.03 \pm 0.01
Putter head displacement from BA to BS (m)	0.006 \pm 0.007	0.08 \pm 0.04
Putter head displacement from BI to FT (m)	0.08 \pm 0.03	0.18 \pm 0.06
Angular displacement change from BS to BI ($^{\circ}$)	2.0 \pm 1.57	4.21 \pm 1.52
Time of max. horizontal linear velocity (s)	1.16 \pm 0.09	0.7 \pm 0.33
Follow-through time (s)	0.34 \pm 0.05	0.43 \pm 0.11

Statistical significance ($P < 0.05$)

There was a significant difference ($P < 0.05$) for mean linear displacement of the putter head between BA to final BS position. However, in contrast the BI to final FT mean linear displacement was not found to differ significantly between the groups. There has not been any definite recommendations put forward for the displacement of the putter head for the relative phases of the putting stroke. Interestingly, the novice displacements tended to agree with the pendulum theory proposed by numerous experts over the years. Their displacements from BA to BS position and BI to final FT position were approximately equidistant. In contrast the experts tended to exhibit the modern theory technique where the putting stroke is executed with the BS being substantially shorter than the FT.

There was a significant difference ($P < 0.05$) for head displacement change between the BS to BI phase. It may be concluded that the more important factor was whether the head was stationary at the point of ball contact. This measurement was however outside the present study's scope.

Vertical displacement for the putter head during the BS and FT phases was significantly different ($P < 0.05$) between the two groups. Experts were characterized by a shallow BS and a more pronounced vertical displacement during the FT. In contrast the novice's vertical displacement during the BS and FT was far greater than both expert phases. The greater variability found in the novice group during the back swing and follow-through phases may have resulted from the breaking of the wrists.

Putting (1998) has referred to the fact that to achieve a crisp ball strike it is desirable to accelerate the putter through the ball hitting area from a slower BS. Consequently, as acceleration is a derivative of velocity it would be expected that the greatest velocity attained would occur at or just after the BI phase. This occurred for the expert golfers (range, 1.05 -1.3 s) but was somewhat more erratic for the novice golfers (range, 0.3 -1.2 s), therefore a significant difference ($P < 0.05$) resulted. Consequently, as expected no significant differences were apparent between the actual maximum horizontal velocities attained. The novice group was however more erratic in the smoothness and velocity pattern during their stroke.

Recommendations for the relative timing of the phases under investigation do not directly exist. However certain authors (Leadbetter, 1997) refer to a slow BS and then an accelerating phase into and through the hitting area. Both groups were characterized by this general trend, the experts to a greater degree than the novices; therefore no significant differences existed. The only significant difference ($P < 0.05$) that did occur was for the FT phase, however, this is not thought to be of any great significance towards putting technique. The main limitations of the study were the homogeneous nature of the selected groups (expert and novice golfers) and therefore any post hoc justifications towards other groups were problematical and indeed limited. Although the collection of data in the controlled environment (golf practice bay) had advantages from the viewpoint of methodological considerations, it nevertheless did not accurately simulate the real external or competitive situation. Finally, the analysis of only one putt per analytical investigation may not always be a true reflection of an individual's technique, and the validity of using a single performance trial per subject as being representative of generalised performance outcomes must be questioned (Bates *et al.*, 1992).

This study assumed that expert golfers were more competent putters than novice golfers. Whilst this appears to be a reasonable claim it may not always be the case. Further improvements to the study could be to incorporate a scoring system to monitor the outcome of individual trials.

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