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Taxonomy of golf putting: Do different golf putting techniques exist?

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Abstract

This study is a preliminary investigation into the use of cluster analysis to determine if different putting techniques existed in a group of club level golfers.

Putting at a hole 4 m away, the performances of 34 experienced golfers (age 55.3 ± 17.8 years and handicap 15.3 ± 6.9, range 3–27) were analysed using putter head kinematic and centre of pressure data. Two distinct putting techniques were identified (named as Arm putting and Body putting), this being the first time different putting techniques have been reported in the research literature. These techniques were defined by parameters related solely to movement of the centre of pressure along the line of the putt. Some players (17 of 34) moved between techniques when performing their putting trials. Neither technique produced more accurate putt results ($P = 0.783$).

Putting technique was further analysed after grouping players according to handicap (similar skill level) or accuracy (similar putting performance). The lack of significant findings when players were re-analysed according to handicap or accuracy highlights the importance of the correct methodological approach to detecting technique differences.

Keywords: *golf putting, technique, cluster analysis*

Introduction

Research into golf putting technique often follows a common theme with players separated into groups based on their handicap (Sim & Kim, 2010; Toner & Moran, 2011; Wilson, Smith, & Holmes, 2007) or level of experience prior to completion of the task (Cooke, Kavussanu, McIntyre, & Ring, 2010; Cooke, Kavussanu, McIntyre, Boardley, & Ring, 2011; Lee, Ishikura, Kegel, Gonzalez, & Passmore, 2008; Tanaka & Sekiya, 2011; Toner & Moran, 2011), or separated by accuracy after completion of the task (Mackenzie, Foley, & Adamczyk, 2011). This method of allocation to group membership indicates that the authors anticipate that similar golf handicap, similar putting experience or similar putting result is associated with similar movements.

Assessing putter head kinematics is most common in the putting biomechanics literature. Being able to strike the ball at optimum speed is an essential and perhaps the most important characteristic of successful putting (Delay, Nougier, Orliaguet, & Coello, 1997; Pelz & Frank, 2000). Separating novice and expert putters based on handicap, Sim and Kim (2010) reported significant differences between groups on putter head velocity at impact but, like others (e.g. Lee et al., 2008), non-significant differences between groups for many parameters including backswing and downswing time.

Analysis of weight transfer, or movement of the centre of pressure (COP), is less common in golf research. Ball and Best (2007) reported on weight transfer styles in the golf swing of a sample of club golfers. Using cluster analysis methods, these authors were able to distinguish groups of golfers based on COP movement patterns. To date, there has been minimal research into movement of the COP during the putting task (Hurrion, 2009).

Previous putting research indicates that there are occasional contradictory results and a high proportion of non-significant results when assessing differences between groups. It can't be discounted that this could indicate that one highly variable technique is used in golf putting or a number of distinct techniques are used. If the latter is true, these techniques are not necessarily a function of novice and expert status, handicap or putt accuracy. Importantly, dividing groups prior to analysis of the movement

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may not be the best scientific method for identifying different techniques.

Cluster analysis is commonly used in biological/taxonomical sciences to find different 'groups' of data. In biomechanics, cluster analysis is not commonly used but it has been used to describe movement patterns in swimming (Wilson & Howard, 1983), gymnastics (Forwood, Clarke, & Wilson, 1985) and weightlifting (Grabe & Widule, 1988), and to describe gait kinetics (Vardaxis, Allard, Lachance, & Duhaime, 1998) and gait kinematics (Kawamoto, Ishige, Mochida, Yoshihisa, & Fukashiro, 2003). In golf research, Ball and Best (2007) used cluster analysis to identify different golf swing techniques. If multiple putting techniques exist but group-based sports biomechanics research is unable to detect them, then the chance of Type II errors is high as players of the same skill level (handicap) will be considered to be doing the same thing even when, in reality, they are not.

Cluster analysis is the task of assigning performances into groups (called clusters) so that the performances in the same cluster are more similar to each other than to those in other clusters. From a biomechanics perspective, a participant's performance is only grouped (or clustered) according to the way they moved during completion of the task. Their score or performance outcome is not used in the clustering process. Each trial is treated individually and it is not necessarily assumed that a participant will perform exactly the same in all trials (Grabe & Widule, 1988).

This study aims to determine whether cluster analysis can be used to identify different putting techniques in a sample of club level golfers.

Methodology

Participants

Thirty-four experienced, right-handed golfers were tested at a private golf club in Melbourne (age 55.3 ± 17.8 years; handicap 15.3 ± 6.9, handicap range 3–27). Victoria University's Human Research Ethics Committee approved the study. All participants volunteered their involvement.

Apparatus

The 4 m putting task was completed on flat ground on the club's practice green (Gott & McGown, 1988; Mackenzie et al., 2011). A pliance® pressure mat (16 × 16 sensor matrix) was used for COP testing. Fifty-six of 256 sensors were deactivated, providing a total of 200 active sensors to allow the pressure mat to sample at 50 Hz (10,000 sensors · s^{-1} maximum scanning rate). Pressure mat data was collected and analysed using novel® pliance®-C 8.3 software. The system's COP measurement accuracy has been validated using COP peak-to-peak amplitude data simultaneously recorded from the pressure mat and an AMTI force platform previously (McLaughlin, 2008) and data passed tests for significant equality using the methods of Londeree, Speckman, and Clapp (1990).

A Panasonic F-15 PAL video camera was placed 12 m in front of the player, off the edge of the putting green, perpendicular to the line of the putt (sample rate 50 Hz; shutter speed 1/2000s). A sample rate of 50 Hz is adequate given that previous authors have reported the maximum frequency content of putter head displacement signal is below 15 Hz (Mackenzie & Evans, 2010). Video footage was used to establish temporal events for each putt and for kinematic analysis using PEAK 2D Motus software. The PEAK Event Synchronisation Unit overlaid a synchronisation pulse from the pliance® system onto the video footage.

Two-dimensional (2D) analysis of the putter head was considered appropriate for a number of reasons. Firstly, Pelz and Frank (2000) suggest that putter head speed is four times more important than line in performing a successful putt. The velocity of the putter head toward the hole can be determined by 2D analysis. Secondly, the method was set up strictly to allow players to feel as comfortable as possible, meaning that the researchers did not place markers on the players or club. It was considered unlikely that accurate 3D analysis could be performed given the nature of the set up. Whilst this outdoor, practice putting green setup does have its limitations, a key aspect of the methodology employed was for the testing to be as ecologically valid as possible. Therefore, golfers wore their typical golf attire including golf shoes, used their own putter, and putted at an actual hole on a putting green they were familiar with.

Procedure

The pressure mat was zeroed before the participant stepped onto it. When the participant settled (not moving and putter head at the address position), pliance® recording software was started. This 'record' command initiated the sync output pulses to the video footage. After putting and when the putt result was evident, the player was asked to step back behind the mat while the pressure recording was saved and the pressure mat zeroed before the next of five putts. The putt result was measured as the radial distance from the centre of the hole and whether the putt was long, short, left, right or holed (Wilson et al., 2007).

For 2D kinematic data, the putter head was manually digitised from 20 fields prior to the start of the backswing to 20 fields past the end of the follow through. This was done to ensure end-point errors were avoided when filtering. Reliability of manual digitisation of the putter head was assessed from *x,y* coordinate data from the same assessor digitising 10 trials one week apart. The 95% levels of agreement are presented for the *x* (0.2 to –1.3 cm) and *y* coordinates (0.34 to –0.54 cm) using the standard deviation of differences for each trial (Bland & Altman, 1986), and indicate a level of manual digitisation reliability within a range of 1.5 cm.

Backswing, downswing and follow through phases and the ball contact event data were extracted from video and used to analyse putter head kinematics and COP data. These events were defined as:

- Backswing phase: Field prior to first movement of the putter away from the ball from the address position, to the field prior to first movement of the putter towards the ball in order to strike it.
- Downswing phase: Field prior to first movement of the putter towards the ball in order to strike it, to one field prior to the point of contact between the putter head and the ball.
- Ball contact: Field of initial contact between the putter head and the ball.
- Follow through: Field of initial contact between the putter head and the ball, to field at the most distal horizontal displacement of the putter head after contact with the ball.

Parameters

Video and pressure data provided 62 parameters for analysis.

- 4 phase duration parameters – backswing, downswing, follow through and total downswing (downswing plus follow through).
- 8 putter head displacement parameters – for the above four phases in horizontal (*x*) and vertical (*z*) directions.
- 8 putter head velocity parameters – at ball contact (*x,z*); maximum during downswing (*x,z*) and time of maximums (*x,z*); minimum (*z*) during downswing and time of minimum.
- 10 COP displacement and position parameters – mediolateral (*x*) and anteroposterior (*y*) COP range during backswing, downswing and follow through; position of COPx,y (relative to address) at end of backswing and ball contact.
- 32 COP velocity parameters – at start and end of backswing, ball contact and end of follow through; local COPx,y maxima and minima throughout the putt and the time they occurred.

Data analysis

Due to the conditions under which testing was performed, numerous trials were lost due to the interference of other players on the putting green (for example, walking in front of the video camera). As players completed testing prior to the club's midweek competition, the putting green was not closed to other players. All players were free to prepare themselves for their round on the putting green. Whilst this did cause an unusually high level of excluded data, it did maintain the task as relatively familiar to the participants.

Putts containing incomplete data were excluded, leaving 108 individual putts for analysis. Each of the 34 players was still represented in this sample of 108 putts. Each individual putt was treated separately in the analysis. Raw data for each parameter were standardised by dividing each value by the range for that parameter (Milligan & Cooper, 1985).

There is no one, easy-to-use cluster analysis method. There are a number of ways of defining clusters, with the two most common – hierarchical and k-cluster – available via a number of statistical analysis software packages. These two techniques are different in their method of cluster creation.

The hierarchical method is agglomerative, meaning that at the start of the process each trial is considered as a cluster (N = 108 clusters), and then in each stage the number of clusters is reduced by 1 when the two most-like trials are joined together. This process continues until all trials are part of one large cluster.

The k-cluster method is a partitioning process, and revolves around a user-selected number of clusters being created from the data. The cluster centre points (centroids or seeds) can be randomly selected, or provided by the user from previous analysis. As such, it is possible to use the hierarchical method to provide the cluster seeds for the k-cluster method to create the optimal solution. The combination of these two procedures is recommended by Hair, Anderson, Tatham, and Black (1995) and was utilised in this paper to derive the final cluster solution.

Numerous 'stopping rules' were implemented to determine the correct number of clusters (Milligan & Cooper, 1985), specifically the Variance Ratio Criterion (Calinski & Harabasz, 1974), R Ratio (Chen & Shiavi, 1990), C-Index (Hubert & Levin, 1976) and Point Biserial Correlation (Jobson, 1992). The authors recommend accessing the original texts for further information on the individual stopping rules. After assessing stopping rule data from the hierarchical clustering method, a specific number of clusters (2–5) were created using k-cluster methods.

The final number of clusters chosen was based on the information provided by the stopping rules and the fit of the final solution. Cluster analysis output also provides the most influential parameters in creating the clusters, revealing where the significant differences lie across cluster groups. Those parameters different across clusters at $P < 0.001$ are reported as the most significant deterministic parameters. This cut-off (P <0.001) was at an arbitrary level that produced a consistent number of significant parameters (n = 11) across the possible cluster solutions for 2–5 clusters. Whilst more parameters were significant below this level for various cluster solutions, the 11 parameters reported here were significant at this level for all cluster solutions. Raw data from these parameters were then analysed for the final two cluster solution using univariate analysis of variance (ANOVA). Effect size (Cohen's d) is also reported.

Results

Two putting techniques were identified through cluster analysis (Table I), summarised as:

1. 'Arm' putting. Relatively small/less displacement of COPx during backswing (4.9 ± 2.7 mm) and downswing (3.9 ± 2.6 mm) phases; velocity of COPx at ball contact closer to zero (on average) (5.2 ± 16.9 mm · s^{-1}), this being lower than the velocity developed in the downswing (25.6 ± 15.7 mm · s^{-1}).
2. 'Body' putting. Relatively large displacement of COPx during backswing (9.6 ± 7.0 mm) and downswing (10.6 ± 4.8 mm) phases; velocity of COPx at ball contact (58.4 ± 22.9 mm · s^{-1}) similar to that developed during downswing (71.8 ± 28.3 mm · s^{-1}).

Table I. Putt results and group characteristics for final clusters (mean ± standard deviation).

	Arm (n = 77)	Body (n = 77)	P	d
Absolute putt result (cm)	36.8 ± 28.5	39.5 ± 32.3	0.783	0.09
Handicap	12.4 ± 5.9	16.4 ± 6.6	0.005	0.63
Age	54.5 ± 16.4	61.5 ± 15.2	0.051	0.43

Absolute putt result was not significantly different between clusters although there was a significant difference between the clusters on handicap (Table I). These data highlight that there are different ways (or techniques) of achieving the same putt outcome. The handicap data indicates a spread of players in each group and, of note, some players appeared in both clusters meaning some used both techniques during their putts.

COPx velocity (mediolateral) at ball contact was consistently the most influential (highest ranked) distinguishing parameter across all cluster solutions. Other parameters changed 'rank' depending on the number of clusters in the solution. It is notable that all 11 of the most influential parameters are COPx parameters. None of the most influential parameters are COPy (anteroposterior) parameters or putter head motion parameters.

Backswing phase

The Arm technique and Body technique are clearly distinguishable by the mean values of influential parameters in the backswing phase. The parameters listed in Table II highlight the significantly greater displacement and velocity of COPx in the Body technique, with effect size data further emphasising the strength of the difference.

Table II. Influential cluster parameters in the putting stroke (mean ± standard deviation).

	Arm (n = 77)	Body (n = 31)	All (n = 108)	d
Backswing				
COPx position end BS (mm)	−2.2 ± 4.2	−7.4 ± 7.7	−3.7 ± 5.9	0.89
COPx range BS (mm)	4.9 ± 2.7	9.6 ± 7.0	6.3 ± 4.8	0.97
MaxCOPx vel away BS (mm · s^{-1})	−22.1 ± 10.6	−42.4 ± 21.2	−27.9 ± 17.0	1.19
Downswing				
COPx range DS (mm)	3.9 ± 2.6	10.6 ± 4.8	5.8 ± 4.5	1.48
MaxCOPx vel to hole DS (mm · s^{-1})	25.6 ± 15.7	71.8 ± 28.3	38.8 ± 29.0	1.59
Time maxCOPx vel away DS (ms)	124 ± 118	247 ± 39	160 ± 115	1.06
COPx vel BC (mm · s^{-1})	5.2 ± 16.9	58.4 ± 22.9	20.5 ± 30.6	1.74
Follow through				
COPx range FT (mm)	8.4 ± 8.2	14.8 ± 8.4	10.3 ± 8.8	0.73
MaxCOPx vel to hole FT (mm · s^{-1})	34.5 ± 24.6	66.2 ± 27.8	43.6 ± 29.2	1.08
Time maxCOPx vel away FT (ms)	159 ± 164	363 ± 172	217 ± 190	1.07
Time maxCOPx vel to hole FT (ms)	234 ± 138	77 ± 104	189 ± 147	1.06

All parameters significantly different between techniques at $P \leq 0.001$.

Putter head kinematic data in the backswing phase shows that backswing duration (530 ± 111 ms vs 564 ± 111 ms; P = 0.16, d = 0.3) and horizontal displacement (21.7 ± 5.3 cm vs 23.2 ± 5.1; P = 0.18, d = 0.29) were not significantly different between the Arm and Body techniques. The larger COPx movement of Body putters during the backswing does not correspond with a significant difference between groups in backswing duration or putter head amplitude.

Downswing phase and ball contact

Table II shows a significantly different approach to COPx motion during the downswing phase for the two techniques. Arm putters have a significantly slower movement of the COPx and smaller COPx displacement during the downswing.

The Arm putts (on average) bring the velocity of COPx close to zero at ball contact. The Body putts maintain COPx velocity at a level only slightly below the maximum achieved during the downswing. Of particular note is that 28 of 77 putts in the Arm technique recorded a negative COPx velocity at ball contact (moving away from the hole). No Body putts displayed this tendency.

The different methods of moving the COPx during the downswing phase and at ball contact did not correspond with a significant difference for putter head velocity at ball contact (154.5 ± 10.1 cm · s^{-1} vs 158.9 ± 11.7 cm · s^{-1}; P = 0.052, d = 0.44). These data, in particular the significance value and effect size, indicate future research should include a greater sample size than was reported in this preliminary study.

Follow through phase

Similar trends continue in the follow through phase with clear differences between the two techniques evident in COPx data (Table II). Body putters continue to produce significantly larger displacements and velocities of the COPx.

Comparative data analysis

Finally, the 11 most influential parameters from cluster analysis output were re-analysed with participants grouped according to handicap and accuracy as reported by previous authors (e.g. Mackenzie et al., 2011; Sim & Kim, 2010). In each analysis, independent group comparison was completed using t-test or Mann-Whitney U depending on the normality of the data set. Significance was determined at P < 0.05.

For putt accuracy, each individual's data was averaged and players allocated to accuracy groups either side of a median putt result (39 cm from the hole). Also, separately, players with single figure handicaps (low handicap or 'expert') and handicaps greater than 18 (high handicap or 'novice') were allocated to groups. This is based on the method of Wilson et al. (2007) who used a handicap range of 10–18 to indicate medium handicap.

Data for all influential parameters were re-analysed using these groupings and are presented in Table III. Of the 11 most influential parameters

Table III. Data for players allocated into groups according to accuracy and handicap for the most influential parameters in formation of clusters at levels 2–5 (mean ± standard deviation).

	Accuracy method		Handicap method	
	More accurate (n = 17)	Less accurate (n = 17)	Low handicap (n = 10)	High handicap (n = 9)
Absolute putt result (cm)	24 ± 9	56 ± 17†	37 ± 18	49 ± 30
Handicap*	13 ± 6	14 ± 7	6.2 ± 2	22 ± 3†
Backswing				
COPx pos end BS (mm)	−3.9 ± 4.3	−4.2 ± 5.8	−2.4 ± 4.8	−4.1 ± 5.4
COPx range BS (mm)*	6.6 ± 3.1	6.9 ± 5.2	5.5 ± 3.4	7.8 ± 4.4
MaxCOPx vel away BS (mm · s^{-1})*	27.6 ± 10.5	30.1 ± 16.7	24 ± 10.7	30.6 ± 10.2
Downswing				
COPx range DS (mm)	6.7 ± 4.2	5.6 ± 4.6	5.1 ± 4.3	8.6 ± 5.8
MaxCOPx vel to hole DS (mm · s^{-1})*	41.9 ± 24.5	42 ± 27.9	33.4 ± 24.4	60.4 ± 26.6†
Time MaxCOPx vel away DS (ms)*	151 ± 100	169 ± 109	119 ± 116	165 ± 115
Ball contact				
COPx vel BC (mm · s^{-1})	22.9 ± 22.3	17.4 ± 30.7	8.3 ± 23.4	26.4 ± 32.4
Follow through				
COPx range FT (mm)*	9.3 ± 5.1	14 ± 13.6	9.2 ± 5.2	17.3 ± 17.9
MaxCOPx vel to hole FT (mm · s^{-1})*	41.5 ± 17.1	48.6 ± 31	39.8 ± 16.2	55.7 ± 37.7
Time MaxCOPx vel away FT (ms)	217 ± 132	204 ± 164	259 ± 135	151 ± 111
Time maxCOPx vel to hole FT (ms)	162 ± 99	224 ± 117	131 ± 112	268 ± 178

*Data not normally distributed so Mann-Whitney U tests conducted instead of independent t-tests. †Significant difference at P < 0.05 between groups.

previously discussed, there was a significant difference between handicap groups for maximum velocity of COPx in the downswing (P = 0.011). All other parameters produced non-significant differences. Of note is that this type of analysis averages player results, and the participant numbers in each group are limited because each player is represented only by their averaged data in the group to which they have been allocated according to handicap or accuracy.

Discussion

The key finding of this paper is the identification of two statistically different golf putting techniques using cluster analysis methods. The two techniques were named 'Arm' putting and 'Body' putting. This is the first time that statistically different putting techniques have been identified. The two techniques were identified using statistical methods that did not assume different techniques would be based on handicap, experience or putt accuracy.

This research also shows that movement of the COPx plays a key role in the identification of different putting techniques. As was the case for the golf swing reported by Ball and Best (2007), movement of the COP should be considered as an important defining aspect of putting technique. Whilst this paper did not have the capacity to investigate the movement of the centre of mass, COPx data suggests that minimising movement of the body during the putting stroke (in coaching terms, maintaining a stable base) is one putting technique. But putting with a stable base is not the only technique, may not be the best technique in terms of putt result, and is not the exclusive domain of players with low handicaps.

Separating players into groups based on handicap or putt result may be a limited approach to identifying technique differences. It is likely that using either of these classification systems could result in Type I and/or Type II errors. Similarly, research that assumes players use the same putting technique on every trial could also result in Type I and/or Type II errors.

When the 11 significantly different influential parameters from the present study were reanalysed using handicap groups or putt accuracy groups, only one of the 11 parameters presented a significant difference. This highlights the possibility of making a Type II error. Whilst previous researchers have conceded that separating players into groups based on handicap is limited (Delay et al., 1997) there is a continuing trend to analyse groups of players separated on handicap or experience as evidenced by more recent publications (Cooke et al., 2010; Cooke et al., 2011; Lee et al., 2008; Mackenzie et al., 2011; Sim & Kim, 2010; Tanaka & Sekiya, 2011; Toner & Moran, 2011; Wilson et al., 2007). This paper demonstrates that rather than relying on these assumptions, techniques can be identified if prior decisions about group allocation are not made, if each trial is treated separately, and if cluster analysis techniques are employed to identify techniques that reflect movement-based differences.

In this study, every putt was treated as a separate item to be clustered. Only 14 of 34 players used the Arm technique for all putts, whereas only three players used the Body technique for all putts. Seventeen players had putts clustered across the two techniques. Since the cluster analysis correctly re-classified 98% of putts using the replication method (three random samples of two thirds of all putts), this confirms that many players did change technique during the execution of their trials. We can only speculate whether changes in technique might be a conscious or unconscious decision on the part of the player, or an inability to maintain the same technique across trials, or a reaction to a poor putt. It is possible, given the profile of this sample of golfers, that performing the same technique consistently is a difficult task. However, as this paper is the first to employ cluster analysis methods in the identification of putting techniques, it is not possible for us to definitively state that consistently performing the same putting technique is, in itself, desirable. This is worthy of future study.

Future work would benefit from using a greater range of putting tasks to establish whether the distinction between putting tasks in this study is part of a continuum of techniques, or whether there is a putting distance, or some other factor, that causes/allows players to switch to a different technique. This study was also limited by the relatively older sample from which the players were drawn (as is typical of mid-week, club-level golfers), however the experimental setup is considered more valid in terms of player performance and the output has demonstrated that identification of technique using cluster analysis is possible even within a relatively small sample of 'similar' golfers.

This paper reports different putting techniques that were largely based on a particular set of parameters related to movement of the centre of pressure (COPx). Given the anecdotal but experienced comments of coaches (e.g. Pelz & Frank, 2000) and other scientists (e.g. Sanders, n.d.), there is no reason to believe more differences or more techniques do not exist, either differences in other parameter sets associated with the Body and Arm techniques (e.g. electromyography, body motion), or differences that form entirely different techniques in other parameter-group dimensions.

This preliminary study has demonstrated that cluster analysis methods can be used to identify techniques. Further, through the use of this innovative analysis method, the authors highlight that the same player can use different techniques. The implications of this are considerable. If the goal of research into golf putting is to identify different techniques, then averaging of an individual's data may not only disguise technique changes within the individual but it would also disguise technique differences within the whole sample. Whilst, ultimately, improved performance is the aim of the coach and/or player, it is important to be able to correctly identify techniques before considered improvements to technique can be made. Furthermore, this study indicates that any sample will inevitably contain individuals that use only one technique mixed in with individuals who use multiple techniques to varying degrees.

Conflict of interest statement

None declared.

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