The Open Sports Sciences Journal

RESEARCH ARTICLE

Analysing the Accuracy of Elite Amateur Golf Players during a Pre-tournament Wedge Test

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Abstract:

Background:

Previous studies identified a medium/strong relationship between the accuracy of wedge play and performance of professional golf players. However, there is a lack of research studies investigating which distance in wedge play has the strongest relationship to performance.

Objective:

The aim of the study was to determine the accuracy with wedges of elite amateur golfers and find out the relationship between accuracy from different distances and short and long-term performance.

Methods:

Ten elite golf players assessed accuracy across distances (45 – 85 m) with Trackman in a pre-tournament wedge test and afterward attended a three-round tournament.

Results:

Percentage error rate decreases (19.0% to 8.4%) with increasing distance, in addition, a significant difference in percentage error rate between 45 m distance and 85 m distance ($p = 0.02$) significant relation between percentage error rate and short term/long term performance indicators at 45 and 55 m.

Conclusion:

Distance control was significantly more difficult (more variable) than direction control with wedges. Significant difference between distances indicates greater difficulty in controlling distance over shorter distances played with wedges. Results show higher importance of accuracy with wedges on performance in shorter (45 and 55 m) versus longer (65, 75 and 85 m) distances. Players performed the stroke more consistently in terms of controlling key impact factors at longer distances, especially in regards to the club head speed, which, together with the ball speed, is the main determinant of the carry distance.

Keywords: Golf, Tournament, Short game, Accuracy, Distance control, Performance, Elite, Golfers.

1. INTRODUCTION

Wedges are usually played from a distance of less than 90 m. The aim of the player is to approach the ball as close as possible to the hole and subsequently achieve greater opportunity to make the putt and thus record a lower score [1]. Accuracy of wedge play depends on direction and distance control of the ball flight and ball roll on the target surface. The direction control is essential when aking full swings with

irons or woods because of difficult adjustment of impact factors. However, with wedges players usually produce shorter swings where distance control is more important in contrast to full swings [2]. Distance control depends on the ball speed (speed of the golf ball immediately after impact), the launch angle (vertical angle the ball takes off relative to the horizon), and the ball spin (the amount of spin (revolutions per minute) on the golf ball immediately after impact). The ball speed is mostly affected by the club head speed (the speed of the club head is travelling immediately prior to impact) and the impact quality with the ball – smash factor (the ratio between the ball speed and the club speed - the amount of energy transferred

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from the club head to the ball). Direction control depends on the ball flight trajectory (curve) and the launch direction (initial direction the ball starts relative to the target line). The ball flight trajectory in the horizontal plane is most affected by the spin axis (the tilt angle relative to the horizon of the golf ball's resulting rotational axis immediately after separation from the club face), which is determined by the angle difference between the face angle (the direction the club face aim relative to the target line at impact), and the club path (the direction the club head moves relative to the target line at impact). Launch direction is affected from 70% to 85% by face angle and from 15% to 30% by club path depending on type of the club [3, 4]. Ball roll on the target surface is influenced by many factors on the green, such as slope, green speed, green firmness, surface inconsistencies, or positions of the hole [5]. Evaluation of wedge play accuracy is determined by the final distance from the target or by the final distance from the target as a percentage of starting distance (percentage error rate) [2, 6, 7].

Previous studies have evaluated wedge play accuracy and performance of professional golf players and investigated the relationship between them [8 - 10]. Pelz [2] found a strong relationship between percentage error with wedges (9-90m) and finishing position in money list on the PGA Tour (the world's highest professional tournament series) as opposed to full swing or putting (no correlation and weak correlation). Pelz [2] mentions finding similar relationships to performance outcomes with amateurs but does not provide supporting evidence. James and Rees [6] found a medium strength correlation between the percentage error of wedges (45-90 m) and world ranking. While such long term performance metrics (*i.e.* world ranking, position on money lists) are not applicable to amateur golfers, their long term performance can be determined by their handicap. Additionally, both groups of players (amateurs and professionals) short term performance can be evaluated by the number of strokes taken per round [11].

Although Pelz [2] and James and Rees [6] identified a medium/strong relationship between the accuracy of wedge play and performance of professional golf players, however, there is a lack of research studies investigating which distance in wedge play has the strongest relationship to performance and subsequently, which parameter affecting accuracy with wedges is key attribute of performance. Determining which distance is most important for performance and which parameter affects accuracy the most would lead to a faster increase in players´ performance. We assume that the percentage error rate will not be significantly different at different distances and that we will find a significant relationship between wedge play performance and short-term performance. Consequently, the aim of the study was to determine the accuracy with wedges of elite amateur golfers and find out the relationship between accuracy from different distances and short and long term performance.

2. METHODS

2.1. Participants

The research sample consisted of male right-handed elite amateur golf players (n = 10, age = 22 ± 3 years, height = 186

± 13 cm, mass = 81 ± 20.5 kg, HCP = 1.2 ± 3.4), who volunteered to participate in the study. The elite level of golf players was defined as the first 100 places in the Official amateur ranking of the Czech Golf Federation. The research was conducted in accordance with the ethical standards of the Helsinki Declaration and Research in the Field of Sports Sciences [12] and approved by the Ethics Committee of Faculty of Physical Education and Sport, Charles University under the number EC 179/2019.

2.2. Design of the Study and Measures

Observational study included two tests: pre-tournament wedge test and three round-tournament. All participants from the tournament were able to participate in the study. Ten of them randomly participated.

Players performed a pre-tournament wedge test one day before a three round-tournament. Participants played three shots to 5 targets (15 shots in total) in the same direction, but at different distances (45, 55, 65, 75, 85 m in this order). The goal of each player was to carry the ball as close as possible to the target *i.e.* the first point of contact between the ball and the ground after the shot was struck.

Accuracy in the pre-tournament wedge test was evaluated by radial (ε_i^y), lateral (ε_i^x) and longitudinal (ε_i) error. Radial error is the absolute distance between final carry impact position of the ball and target, lateral error is the side deviation from the target and longitudinal error is the length deviation from the target. Radial and lateral error was measure by 3D Doppler Radar Trackman 4 (Trackman, Denmark). The longitudinal error (ε_i) was obtained using the Pythagoras theorem, as it is the hypotenuse of the right triangle relating both legs defined by the lateral error ε_i^x and the radial error ε_i^y [13].

$$\varepsilon_i = \sqrt{(\varepsilon_i^y)^2 - (\varepsilon_i^x)^2} \qquad \textbf{(1)}$$

From the radial error, the percentage error rate was calculated (final distance as a percentage of starting distance). For the following analysis, the impact factors - the clubhead speed (CHS), the smash factor (SF), the ball speed (BS), the launch angle (LA), and the ball spin (SPIN) were collected by 3D Doppler Radar Trackman 4and coefficient of variation (CV) was calculated (standard deviation (s) multiplied by 100 and divided by the mean($\bar{x}$). "

$$CV = \frac{s * 100}{x} \qquad \_ \qquad \textbf{(2)}$$

The short-term performance of the players during the three-round tournament was evaluated by the number of strokes in the first, second, and third rounds and by total score, best score and mean score from the first two rounds. A cut was made after the second round. Two players did not make the cut, therefore evaluation of third-round score and total score included only 8 players. The long-term performance level was evaluated by handicap (lower handicap equals better performance).

2.3. Procedures

The test was held on a driving range at a local golf club where participants played shots from grass. The device Trackman 4 (Trackman, Denmark) was placed 3 meters behind the player so that it was possible to measure all parameters. The display device was placed in front of the player so that he could observe his results. Participants were tested by researchers.

2.4. Statistical Analysis

The normal distribution of the dataset was verified by the Shapiro-Wilk test for each parameter. The strength of the relationship between long and short-term performance and accuracy in pre-tournament wedge test (radial error, percentage error rate)was determined by Kendall tau as well as the relationship between the carry of each shot and the impact factors. Significant differences between distances (in parameters -radial, lateral, longitudinal error, percentage error rate, and coefficient of variation of impact factors) were evaluated by Kruskal-Wallis test with pairwise comparisons using Wilcoxon rank sum test for non-normal distributed data and one way ANOVA with Tukey post hoc test for normally distributed data. Only statistically significant results ($p<0.05$) and coefficients above $\tau = 0.3$ were accepted. Microsoft Excel software was used for processing basic data and R v3.5.2 software (Vienna, Austria) for statistical analysis.

3. RESULTS

Fig. (**1**) shows absolute radial, lateral, longitudinal error and mean percentage error rate. At all distances lateral error (45 m: 1.6 m; 55 m: 2.4 m; 65 m: 2.0 m; 75 m: 2.5 m; 85 m: 3.7 m) was lower than longitudinal error (45 m: 8.2 m; 55 m: 6.3 m; 65 m: 6.5 m; 75 m: 9.1 m; 85 m: 5.4 m) with the highest differences being 6.6 m at 75 m and 6.5 m at 45 m and lowest difference 1.7m at 85 m. (45 m: 6.5 m; 55 m: 3.9 m; 65 m: 4.5 m; 75 m: 6.6 m; 85 m: 1.7 m). A significant difference was found between lateral and longitudinal error ($p < 0.001$). No significant differences in radial errors in tested distances were found. Mean percentage error rates was 19.0%, 13.0%, 11.1%, 12.9%, and 8.4% with increasing distance and mean percentage error 12.9% for all distances. The large difference between minimum (4.9%) and maximum (41.2%) error was found at a distance of 45 m. A significant difference was found in the percentage error rate between 45m distance and 85 m distance ($p = 0.02$).

Significant relationships were found between percentage error rate and handicap ($\tau = 0.64$; $p = 0.01$), score in first round ($\tau = 0.68$; $p = 0.01$), mean score from first and second round ($\tau = 0.67$; $p = 0.01$), and best score ($\tau = 0.78$; $p = 0.003$) at 45 m test and between percentage error rate and handicap ($\tau = 0.58$; $p = 0.03$) and best score ($\tau = 0.58$; $p = 0.03$) at 55 m distance. Mean percentage error of all distances significantly correlates with score in first round ($\tau = 0.54$; $p = 0.05$) and best score ($\tau = 0.6$; $p = 0.02$) (Table **1**).

Statistical results revealed a significant difference between the coefficient of variation of the ball spin and all other impact factors at 45 m, 55 m, 65 m, 75 m and 85 m distance ($p < 0.02$). All parameters had higher coefficient of variation at 45 m (CHS: 6.9%; SF: 6.8%; BS: 13.5%; LA: 12.0%; SPIN: 29.4%) than at 85 m (CHS: 2.5%; SF: 3.1%; BS: 3.9%; LA: 8.8%; SPIN: 22.7%). Significant differences were found in coefficient of variation of the club head speed between 45m distance and 65m distance ($p = 0.02$), 75m distance ($p = 0.01$), and 85m distance ($p = 0.01$). No significant differences in the smash factor, the ball speed, the launch angle or the ball spin in tested distances were found (Table **2**).

Carry distance of strokes has a significant relationship with ball speed (45 m: $\tau = 0.83$; $p < 0.001$; 55 m: $\tau = 0.75$; $p < 0.001$; 65 m: $\tau = 0.78$; $p < 0.001$; 75 m: $\tau = 0.79$; $p < 0.001$; 85 m: $\tau = 0.63$; $p < 0.001$; total: $\tau = 0.87$; $p < 0.001$), with club head speed (45 m: $\tau = 0.46$; $p = 0.001$; 55 m: $\tau = 0.31$; $p = 0.002$; 65 m: $\tau = 0.33$; $p = 0.01$; total: $\tau = 0.65$; $p = p < 0.001$), with launch angle (65 m: $\tau = -0.39$; $p = 0.003$) and with ball spin (65 m: $\tau = 0.56$; $p < 0.001$).
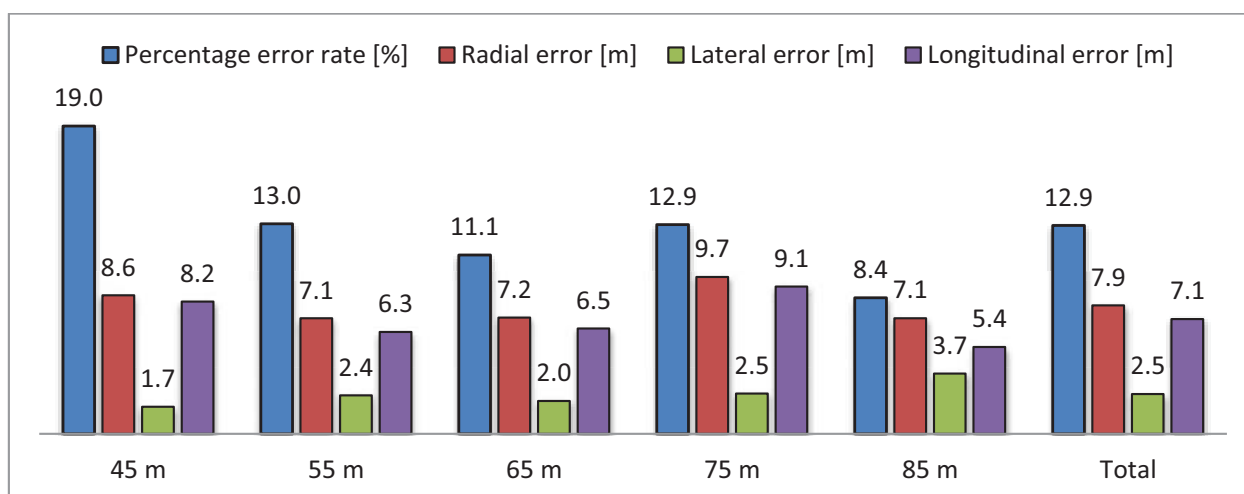

Fig. (1). Radial, lateral and longitudinal error and percentage error rate at different distances.

Table 1. The relationship between percentage error rate in different distances and short, long term performance as determined by Kendall rank correlation.

-	Starting Distance [m]	Long Term Performance	Short Term Performance			
		Handicap	First round	Second round	Best score	Mean score
Percentage error rate [%]	45 m	**0.64***	**0.68***	0.34	**0.78****	**0.67****
	55 m	**0.58***	0.28	0.32	**0.58***	0.43
	65 m	-0.07	0.21	-0.16	0.23	0.00
	75 m	-0.05	0.41	-0.32	0.16	-0.11
	85 m	0.07	0.07	0.16	0.05	-0.05

Legend:* $p < 0.05$; ** $p < 0.01$

Table 2. Coefficient of variation of impact factors at different distances.

-	45 m	55 m	65 m	75 m	85 m
CV CHS [%]	6.9	4.4	3.0	2.9	2.5
CV SF [%]	6.8	6.2	3.9	5.4	3.1
CV BS [%]	13.5	7.4	5.8	8.2	3.9
CV LA [%]	12.0	10.4	9.8	9.7	8.8
CV SPIN [%]	29.4	39.5	28.9	26.3	22.7

Legend: CV –the coefficient of variation, CHS – the club head speed, SF – the smash factor, BS – the ball speed, LA – the launch angle, SPIN – the ball spin.

4. DISCUSSION

The results in this study of amateur golfers can be compared to those from professional golf players in studies by Cochran and Stobbs [7], Pelz [2] and James and Rees [6]. Cochran and Stobbs [7] found a median percentage error of 7.8% (9-65 m), Pelz [2] showed mean percentage error rates between 13% and 26% (for less-than-full-swing wedge shots – 35-55 m) and James and Rees [6] median percentage errors of 5.2% to 6.5% (45-90 m). The current study found similar results to Pelz [2] - mean percentage error 12.9% for all distances. Other studies show lower percentage errors [6, 7] due to the higher performance level (Fig. **1**).

The percentage error rate decreases (19.0% to 8.4%) with increasing distance (45-85 m), however, radial error is similar at all distances (45 m: 8.6 m, 55 m: 7.1 m, 65 m: 7.2 m, 75 m: 9.7 m, 85 m: 7.1 m). Results indicate that players are not more accurate at shorter distances as would be logical. Furthermore, when we consider starting distance from the target players, we are less accurate in percentage error rate at shorter distances. A significant difference in percentage error rate was found only between 45 m and 85 m distance ($p = 0.02$). Longitudinal error is significantly lower than lateral error ($p < 0.001$) as in the study by Pelz [2]. This suggests that distance control is more difficult than direction control with the wedges. Furthermore, based on the results of this study, accuracy is apparently more difficult for shorter distances played with the wedges. As soon as the strokes required become closer to full swings, the outcome is more accurate from the perspective of percentage error rate. This fact can be explained by training procedures where strokes at longer distances are typically played at the driving range where players are more focused on carrying distance as opposed to strokes at shorter distances which are usually practiced at the chipping green where players also control the roll of the ball on the green.

A further aim of the study was to determine the accuracy with wedges of elite amateur golfers and their relationship to short and long-term performance. The results of this study show significant relationships between mean percentage error of all distances and score in first round and best score ($\tau = 0.54$; $p = 0.05$; resp. $\tau = 0.6$; $p = 0.02$). The wedge test used in this study was a determinant of short term performance – score in the first round (next day after testing) and each player's best score in the tournament. We assume that results would also be significant with scores in the second round, third round and total score if measured right before each round. Furthermore, James and Rees [6] found similar medium strength correlations between percentage error performed with wedges (45-90 m) and world ranking ($r = 0.56$). Additionally, Pelz [2] found a strong correlation between the percentage error of wedges (9-90m) and position on the PGA Tour money list. This study indicates the importance of short game distance control to the performance of amateur golfers and mirrors the findings of similar studies in professional golf [2, 6]. At 45 m a significant relationship was found between percentage error rate and handicap ($\tau = 0.64$; $p = 0.01$), score in first round ($\tau = 0.68$; $p = 0.01$), mean score ($\tau = 0.67$; $p = 0.01$), and best score ($\tau = 0.78$; $p = 0.003$) and at 55 m there was a significant relationship with first round ($\tau = 0.54$; $p = 0.05$) and best score ($\tau = 0.6$; $p = 0.02$). However, the results do not show a significant relationship between percentage error rates and longer distances (65, 75 and 85 m). The results suggest a higher impact on the performance of accuracy with wedges over shorter distances (45 and 55 m) than longer distances (65, 75 and 85 m). Based on the findings of this study, we suggest that amateur players should practice distance control with wedges over distances shorter than 55 m to improve performance.

With increasing distance, all coefficient of variation of impact factors decreased (Table **2**). Players performed strokes in a more stable manner in terms of control of impact factors at longer distances. This is evident with a significant difference in variations of the club head speed at 45 m distance and 65 m

distance (p = 0.02), 75 m distance (p = 0.01), and 85 m distance (p = 0.01). Higher variations of club head speed at shorter distances are due to players exploring their swings to bring percent error down [14]. Gryc *et al.* [15] found the coefficient of variation of the club head speed at full swing with mid-irons to be 8.9% and 7.8% with driver contrary to the results of this study – 2.5% at 85 m distance. The difference between results can be explained by the number of repetitions undertaken. A significantly higher coefficient of variation of the ball spin against other impact factors (p < 0.02) was found, which can be caused by the variable quality of driving balls. There are many factors which effect the ball spin, such as club and ball design, friction, and impact location, that was not examined [3]. The main determinant of carry distance was the club head speed (total: τ = 0.65; p = p < 0.001) and its relationship to the ball speed (total: τ = 0.87; p < 0.001). Based on the presented results, we suggest that players should practice a repeatable motion that will lead to inter-individual stability of impact factors influencing distance control. Players should, therefore, use equipment that allows monitoring of impact factor parameters in individual shots, such as the 3D Doppler radar TrackMan as used in this study and as is used by many PGA Tour players. Technology, such as high speed video-cameras [16], is positively influencing performance development in golf. To add to research in this area in future studies, we will focus on the effect of using radar as immediate feedback on performance development in highly skilled golfers.

In our opinion, the results are excellent helpers for both coaches and players in the training process. However, we must also state the limits of this study that affect the results. The number of repetitions in the pre-tournament wedge test at each distance is relatively small. This was done for pre-tournament feasibility. More repetitions would cause more test reliability. Also, a larger research sample would produce more credible results that could be generalized to elite amateur players.

CONCLUSION

The aim of the study was to determine the accuracy with wedges of elite amateur golfers and find out the relationship between accuracy from different distances and short and long term performance. The percentage error rate decreases (19.0% to 8.4%) with increasing distance (45-85 m) indicates greater difficulty in controlling distance over shorter distances played with wedges. This is shown by the longitudinal error being significantly lower than lateral error, thus showing distance control is more difficult than direction control with the wedges. Furthermore, results show accuracy with wedges over a shorter distance (45 and 55 m) has a greater impact on performance than accuracy over longer distances (65, 75 and 85 m). Additionally, this study indicates that distance control with wedges is as important to the performance of amateur golfers as it has been proven to be with professional golfers [2, 6]. Players perform the stroke with greater stability in terms of impact factors at longer distances, especially in relation to variations of the club head speed. Furthermore, results show the club head speed and its relationship to the ball speed are the main determinant of the carry distance.

The results of this study should primarily serve coaches and players in practice for the enhancement of performance. The content of the training should include distance control with wedge play, especially at short distances (45 and 55 m), which have a strong relationship with performance and at these distances, players achieve a higher percentage error rate. To improve distance control with wedges, it is important to focus on lower variations of club head speed. Finally, we suggest that shorter distance tests of distance control with wedges should be used by coaches for the evaluation of training and objectification of a player's progress [17].

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the ethics committee of Faculty of Physical Education and Sport, Charles University, under the number EC 179/2019.

HUMAN AND ANIMAL RIGHTS

No Animals were used in this research. All human research procedures were followed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

All participants were informed about the protocol and gave their written informed consent before participating in the study.

STANDARDS OF REPORTING

STROBE guidelines have been followed in this study.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available in the Zenodo at https://zenodo.org/record/5638079#.YYDxGp 7MI2w, reference number DOI 10.5281/zenodo.5638078.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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