THE DEVELOPMENT OF THE *PUTT.IT.IN* MONITORING DEVICE AND THE ESTABLISHMENT OF ITS RELIABILITY: A SOLUTION FOR PUTTING-IN ANALYSIS IN GOLF

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Abstract

Background: The accurate transfer of information on the athletes' performance in any sport is essential in enhancing the performance and overall coaching process. The provision of such information is favourable only if it is reliable. A cost-effective golf putting monitoring device namely the *Putt.It.In* was developed for analysing a golfers' putting performance. **Objectives:** This study aims to investigate the reliability of the instrument in measuring the backswing distance, front swing distance, clubhead speed, ideal front swing distance and swing angle. **Methods:** A semi-professional golfer (30 years of age ± 5.0 years' experience) executed four strokes repeatedly from a distance of 2 m and 1 m using a Ram Zebra Mallet putter on a PGM golf mat. The intra-class correlation (ICC) coefficient is employed to test the reliability of the device whilst the Kolmogorov/Smirnov test was utilised to further reaffirm the reliability of the application in measuring the aforementioned parameters over test re-test between first two strokes of 2 m distance and the last two strokes of 1 m distance. **Results:** The ICC reveals 0.98 and 0.96 for both test 1 and 2, as well as a Cronbach's Alpha of 0.99 and 0.96, respectively suggesting excellent consistencies in the overall observations. Moreover, the Kolmogorov/Smirnov test re-test indicates that there is no significant difference between the first two 2 m strokes $p > 0.05$, and subsequent two 1 m strokes $p > 0.05$ highlighting its ability to recognise the pattern of the strokes applied in the four successive strokes. **Conclusion:** The *Putt.It.In* monitoring device is found to be reliable in measuring the backswing distance, front swing distance, clubhead speed, ideal front swing distance and swing angle. Professional and semi-professional golfers as well coaches could consider *Putt.It.In* device in monitoring strokes related parameters to enhance their performance due to its effectiveness in providing information on putting performance.

Keywords: Golf, Putting, *Putt.It.In* device, Reliability measurements, Athlete monitoring

Introduction

The advent of instrumentation has somewhat aided researchers to quantify what has longed to be abstract and manipulate it into a reliable measure. The quantification of such measures is hypothesised to improve athletes' performances which are an integral part of performance analysis in sports science. Putting is the act where the golfer tries to get the golf ball rolling into the hole on the green. The motion of putting is conceptualised as a double-pendulum motion where the shoulder and wrist act as hinges and the arm and the club as a rigid arm for the swing (Neal & Wilson, 1985). Both of the golfer's hands grip the putter and create a pendulum motion with fix height of the shoulder by swinging the club backwards and forward as illustrated in Figure 1 (a). Nonetheless, to assume this condition one should consider various factors involved as nonlinearities in human movements

which they are bounded by. For instance, novice golfers do emulate the pendulum motion as shown in Figure 1 (b), but it differs compared to high-level golfers (Delay, Nougier, Orliaguet, & Coello, 1997).
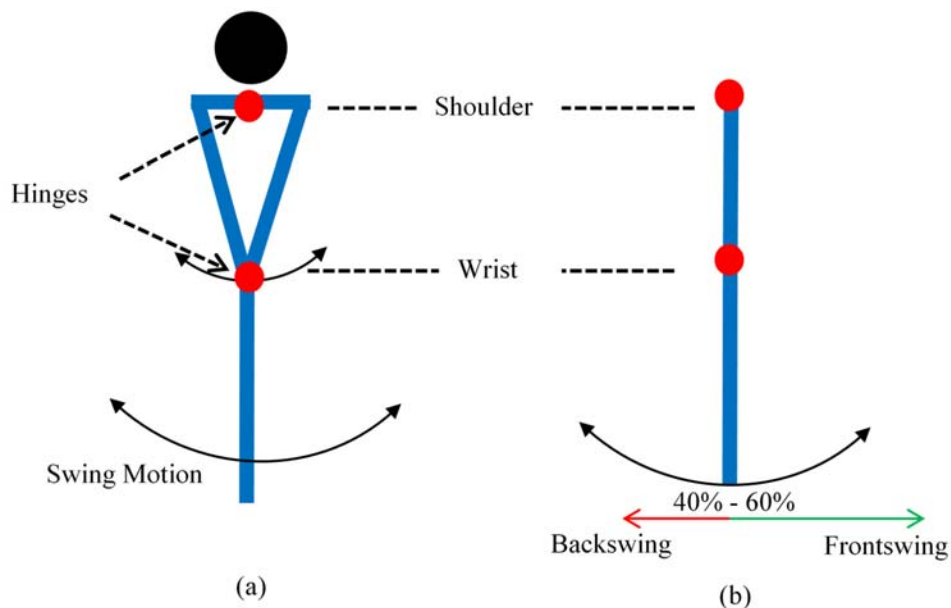

Figure 1: (a) Swing Motion Double Pendulum (b) Rigid single Pendulum

A famous author, Peter Dobereiner once said: **"Half of golf is fun: the other half is putting"**. His saying is rather true as putting alone covers nearly 43%, and it may even go up to 80% of overall strokes in a game depending on the exhaustion of the mental or physical state of the golfers (Pelz & Frank, 2000; Mackenzie & Evans, 2010). In consequence, a golfer's stroke as a whole will decrease once their putting game has improved.

There are three major actions in a putting motion that begin with the backswing, followed by downswing viz. the moment of impact and lastly the follow through. A comparison between novice golfers and experts for the entire motion was made to distinguish important parameters (Sim & Kim, 2010). It was identified that there are a number of parameters that shows notable differences between the aforementioned two groups. Nonetheless, the objective of this study corresponds to one of the findings where the time to impact and the peak of the velocity does not change. However, with respect to the club head's speed, a novice golfer may show more deviation compared to experts as the length, and weight of the putter varies (Sim & Kim, 2010). This condition is seen as the major factor for beginners to learn and improve their putting skills, where the consistency fluctuates on each swing. On the contrary, when describing the immediate impact of the ball, it is too sudden, and it may be disregarded (Coshran & Stobbs, 1968).

The mechanics of impact of golf putting may be described as follows. As the clubhead hits a stationary ball upon impact, the ball will subsequently roll into the hole with the right amount of force assuming that the direction is correct. If the golf ball is within the vicinity of the hole means that the accuracy of the player hitting the ball is relatively high. Additionally, a certain amount of impulse is required to ensure the ball is approximately near to the hole based on the impulse variability model study from previous researchers (Schmidt, Zelaznik, Hawkins, Frank, & Quinn, 1979). Hence, if the putting motion is occupying at the same time, then the speed disparity is not accounted for between different degrees of skill in putting. Therefore, the development of the putting measurement device is primarily governed by this notion.

It was opined that on handling a golfer's motor learning ability, different manner has to be established (Manoel & Connolly, 1995). Therefore, to expedite the learning process, a concept of an ideal follow-through motion was incorporated as a drill for a player to imitate proper putting. It was suggested that the follow-through for an expert are relatively higher than the 40:60 ratio, nonetheless, novice golfers only showed a 50/50 ratio (Sim & Kim, 2010). The 40:60 ratio for putting stroke was introduced to educate learners to exert a suitable amount of

speed. The measurement device developed is able to estimate the follow-through distance with regards to the backswing of the stroke as depicted in Figure 1 (b). For instance, if the player pulls the club 20 cm backwards, an indicator will display the predicted length of follow-through of 30 cm before the moment of impact.

Therefore, it is postulated that an ideal follow-through distance measured by means of a Graphical User Interface (GUI) and real-time monitoring will induce faster results for a better speed throughout the swing action owing to the direct communication between the golfer and the coach. Furthermore, by having this monitoring system in place, it provides the golfer with a solution towards having a consistent follow through putt. Such parameters could easily help golfers and coaches to extract the significant information for a better overall scoring (Toner, Moran, & Jackson, 2013). *Putt.It.In* can be considered as a training device for golfers to emulate an ideal follow through putt. Therefore, the present study aims to test the ability of the device to measure the golf putting strokes related parameters namely; the backswing distance, front swing distance, clubhead speed, ideal front swing distance and the swing angle of a golfer in real-time.

Materials and Methods

Device's description:

The *Putt.It.In* device quantifies the putting stroke of the golfer which includes an instrumented glove, shoe insole for postural balance and interactive software that would enable effective interaction between coaches and athletes. The putting motion was measured using a device that was attached to the glove as shown in Figure 2 that incorporates an accelerometer and a pulse sensor. The fusion between the sensors could extract a variety of information in real time, however, in this study, the variables that are of concern are Backswing Distance, Front Swing Distance, Club Head Speed, Ideal Front Swing Distance and Swing Angle. The data is transmitted via Bluetooth to a PC and extracted into a Graphical User Interface (GUI). Real-time values are recorded and analysed after the golfer's full motion has been captured.

Figure 2: *Putt.It.In* Instrumented Glove

Experimental Protocol

The experimental protocol conducted in the present study is implemented in two parts. In the first part (Test 1, 2 m distance), the golfer was instructed to putt in the golf into the hole from a distance of 2 m and repeat the same stroke in a similar manner. Whilst, in the second part (Test 2, 1 m distance), the golfer was required to putt in the golf into a hole from a distance of 1 m. This is deemed necessary in order to test whether the device has the ability to recognise the pattern applied by the golfer based on the measured parameters in the two aforementioned distances. This experimental protocol is adapted from previous researchers (Ertan, Kentel, Tümer, & Korkusuz, 2005).

Data Collection Procedure

Only one male golfer participated in this study. The golfer is of 30 years of age with five years of golfing experience and has a double-digit handicap at an average of 96 strokes. The golf putter that was used in this study is the Ram Zebra Mallet with a length of 89 cm, and the Callaway Big Bertha golf ball. A PGM putting mat with a slope of 10 cm is the platform utilised in the experimental study.
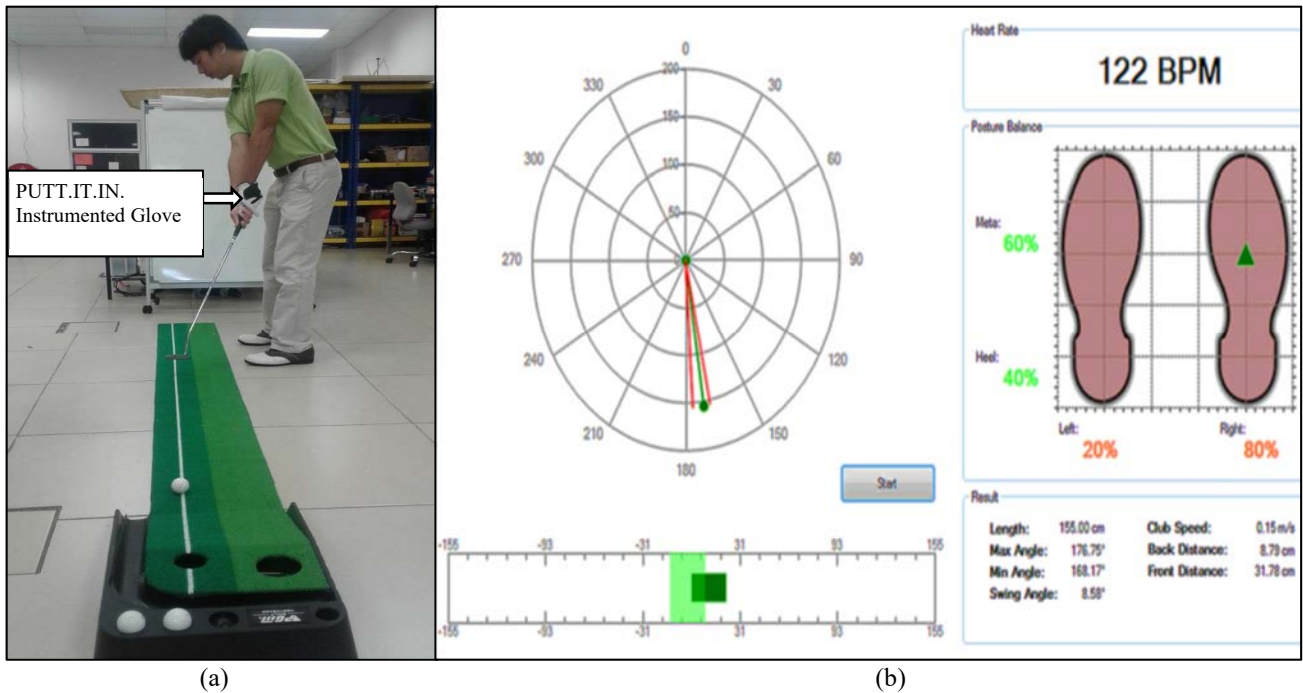

Figure 3: (a) Experimental setup (b) *Putt.It.In* GUI

As described by Klampfl et al. (2013), yips may occur during a putting stroke that in turn cause the ball to lose control. Therefore, the golfer was asked to putt on the white line markings into a hole size of 6.5 cm in diameter. The golfer was given a couple of practice swings and strokes from 1 m and 2 m away from the hole as in depicted in Figure 3 (a). After six trials, the data was collected only if the golfer putts the ball into the hole. For each distance of 1 m and 2 m, two sets of data were recorded in the *Putt.It.In* GUI as shown in Figure 3 (b).

Data Analysis

The intra-class correlation coefficient (ICC) was employed to measure the reliability of the device over test re-test between first two strokes of 2 m distance, and the lasts two strokes of 1 m distance at a confidence level of $p \leq 0.05$. On the other hand, the Kolmogorov/ Smirnov test was applied to reaffirm the consistency of the aforementioned measurements. Scatter plots were drawn to illustrate the summary for the relationship between the observed strokes of the golfer in relation to the stroke distance and the measured parameters. The data for the total of four tests were analysed and evaluated using SPSS version 20 for Windows and XLSTART add in version 2014 for Windows.

Results

Table 1: Descriptive statistics of the measured variables.

Variable	Obs.	Min	Max	M	SD
1st test (2m)	5	-18.890	28.335	9.225	18.871
2nd test (2m)	5	-24.247	36.371	11.640	24.077
1st test (1m)	5	-15.206	22.809	7.007	14.912
2nd test(1m)	5	-9.463	19.561	7.026	11.644

Table 1 projects the descriptive statistics of all the variables measured. The periods of the observation (tests), the number of parameters (i.e. backswing distance, front swing distance, club head speed, ideal front swing distance and swing angle) over which the golfer was examined, the minimum, maximum boundary, the mean as well as the standard deviation are displayed.

Table 2: Reliability Statistics

Measurements	A. M. for ICC	95% CI Lower Bound	95% CI Upper Bound	F	df	Sig.	Cronbach's Alpha	N
Test 1 (2m)	0.98	0.75	0.99	67.9	19	.001*	0.99	2
Test 2 (1m)	0.96	0.57	0.99	22.6	4	.005*	0.96	2

Table 2 reveals the inferential statistics for the reliability test. The intra-class average measure (A.M. for ICC) for both test 1 and 2 reveals 0.98 and 0.96 respectively which explains that 98% and 96% of the variance and the means of the two measurements in the overall analysis is accurate $p < 0.005$. Similarly, a Cronbach's Alpha coefficient for the two tests indicates 0.98 and 0.96 which suggests excellent consistencies in the general observations (N).

Table 3: Inferential Statistics of the Kolmogorov/Smirnov test re-test

Test-retest	Observation	D	P value
Test 1 (2m)	Obs. 1	0.20	0.99
	Obs. 2		
Test 2(1m)	Obs. 3	0.21	0.97
	Obs. 4		

Table 3 indicates the inferential statistics of the Kolmogorov/Smirnov test re-test. The two periods of testing, the observations, the D-statistics as well as the p values are shown. It can be observed from the tabulated results that test 1 (2m) (observations 1 and 2) reveals a D-statistics of 0.20 and a corresponding p-value of 0.99 whereas test 2 (1m) (observations 3 and 4) indicates a D-statistics of 0.21 and a p-value of 0.97. The results from this table reflect that both the p-value of test 1 and 2 are > 0.05 which suggests that there is no statistically significant difference between test 1 and 2 as well as tests 3 and 4. The results are significant as it affirms the reliability of the *Putt.It.In* measurement device in recognising the pattern of the strokes executed by the golfer.
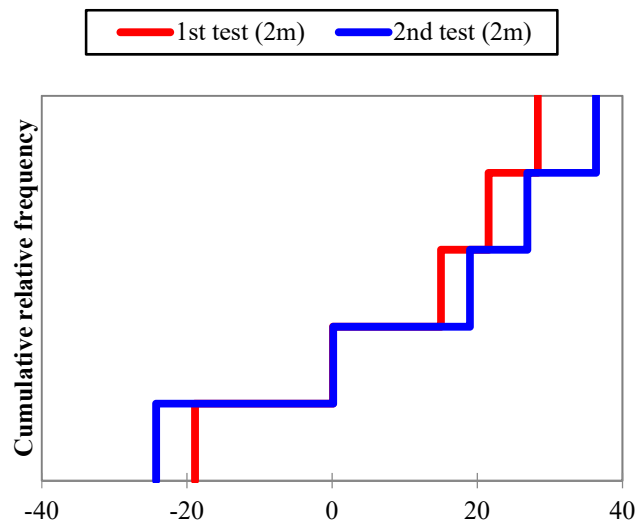
Figure 4: Cumulative distribution frequencies plots of the observations between test 1 and 2 of 2 m distance

Figure 4 demonstrates the relative association of the observations between test 1 and 2 of the 2 m distance stroke. Closely related relationships between test 1 and 2 can be observed; this indicates that there are no inconsistencies on the relative observations between the two tests.
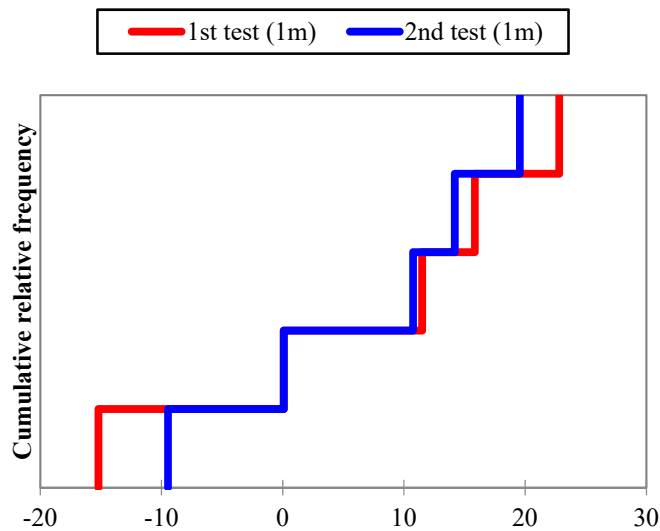

Figure 5: Cumulative distribution frequencies plots of the observations between test 1 and 2 of 1 m distance

Figure 5 reveals the relationship of the observations between test 1 and 2 of 1 m distance stroke. From the figure it can also be seen that there exists a closely related pattern between the tests, this in turn also indicates that there are no apparent discrepancies on the relative observations made between the two tests. The results also highlight the consistency of the device in evaluating and recognising the pattern of the golfer's stroke from the same measured distance.

Discussion

The findings of the present study show that *Putt.It.In* device is reliable in measuring the backswing distance, front swing distance, clubhead speed, ideal front swing distance, and swing angle. Table 2 lists the significant parameters to ensure the reliability of the *Putt.It.In.* device. As suggested through the analysis by means of the ICC as well as the Cronbach's Alpha coefficient, the consistencies with respect to the general observations of the both test cases are rather accurate. Furthermore, the reliability evidence as per the Kolmogorov/Smirnov shown that strokes performance of the golfer can be interpreted in a relatively the same pattern from series of strokes when similar posture is sustained. The information on the strokes parameters measured by the device collected has specified that there is a strong association between the strokes of similar distances (Table 3). This finding is in agreement with a study conducted by Ertan et al., (2005) who inferred that the advances in technology in recent years have led to a wide variety of systems that allow coaches and athletes to aid decision-making process to further enhance their performance. These systems have been developed from scratch for specific purposes and differ significantly from one another in terms of their ability to provide information to their end users. It is, therefore, pertinent and necessary for every application to be tested in order to ascertain whether it has the capability to evaluate what it is initially designed to evaluate (Abdullah, Musa, Maliki, Kosni, & Suppiah 2016; Gay, Mills, & Airasian, (2011).

There is also sufficient evidence to claim that the *Putt.It.In* device was able to make reliable measurements of the strokes performance of the golfer when subjected to test re-test procedure. The device could measure the strokes of the golfer in a consistent manner within same distance and similar body postures. This discovery is in line with the results obtained by Ertan et al., (2005) when they applied test re-test technique of Kolmogorov/Smirnov as well as the ICC to ascertain the reliability of a newly developed device in archery. Reliability is amongst of the most important elements of test quality. It has to do with the consistency, or reproducibility, or an instrument's performance on the test. For instance, if we were to administer a test with high reliability to an application on two different instances, it could be very likely to reach the same conclusions about the instrument's performance both times. Conversely, a test with less reliability might result in different scores for the examinee across the two test administrations. If a test yields inconsistent scores, it may be unethical to take any substantive actions on the basis of the test (Carmines & Zeller, 1979). The finding of reliability from this study has indicated that there are not many discrepancies on relevant observations between similar distance strokes, highlighting the consistency of the device in evaluating the golfers' strokes performance (see Figure 4 and 5).

Conclusion

Amongst essential features for any monitoring devices, are the ability to generate information, transfer the information in a way that is coherent to both the coach and the athlete as well as the user-friendliness of the device. This study reveals that the *Putt.It.In* device is efficient in providing information on the related golf performance parameters viz. the backswing distance, front swing distance, clubhead speed, ideal front swing distance and the swing angle of a golfer in real-time. The nature of the device such as wearability, user friendliness and effective transfer of information, made it easier to acquire golfers strokes related performance with the purpose of accelerating their development and enhancing their performance. It is our hope that professional and semi-professional golf clubs could consider the *Putt.It.In* device in performance analysis of their golfers due to its effectiveness in the analysis of golfers stroke related performance parameters.

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