Reliability of an experimental method to analyse the impact point on a golf ball during putting

Ashley K. Richardson, Andrew C. S. Mitchell and Gerwyn Hughes

This is an Accepted Manuscript of an article published by Taylor & Francis in Sports Biomechanics on 23rd June 2015, available online: https://dx.doi.org/10.1080/14763141.2015.1052542

Richardson, A.K., Mitchell, A.C.S. and Hughes, G. 2015. Reliability of an experimental method to analyse the impact point on a golf ball during putting. *Sports Biomechanics*. 14(2): pp.206-215. doi: 10.1080/14763141.2015.1052542

Reliability of an experimental method to analyse the impact point on a golf ball during putting.

Ashley K. Richardson[1], Andrew C. S. Mitchell[2], & Gerwyn Hughes[3]

[1]*Division of Sport and Exercise Sciences, School of Social and Health Sciences, Abertay University, UK.* [2]*Department of Sport Science and Physical Activity, Faculty of Education and Sport, University of Bedfordshire, UK.* [3]*Sport, Health and Exercise Subject Group, School of Life and Medical Sciences, University of Hertfordshire, UK.*

KEYWORDS: Biomechanics, reliability, golf putting, kinematics.

Abstract

This study aimed to examine the reliability of an experimental method identifying the location of the impact point on a golf ball during putting. Forty trials were completed using a mechanical putting robot set to reproduce a putt of 3.2 m, with four different putter-ball combinations. After locating the centre of the dimple pattern (centroid) the following variables were tested; distance of the impact point from the centroid, angle of the impact point from the centroid and distance of the impact point from the centroid derived from the X, Y coordinates. Good to excellent reliability was demonstrated in all impact variables reflected in very strong relative (ICC = 0.98 – 1.00) and absolute reliability (SEM% = 0.9 – 4.3%). The highest SEM% observed was 7% for the angle of the impact point from the centroid. In conclusion the experimental method was shown to be reliable at locating the centroid location of a golf ball, therefore allowing for the identification of the point of impact with the putter head. Therefore is suitable for use in subsequent studies.

Words: 174

Introduction

Putting accounts for 43% of shots made in golf (Pelz, 2000). Despite a number of studies having identified a positive correlation between successful putting performance and overall score (Dorsel & Rotunda, 2001; Quinn, 2006; Wiseman & Chatterjee, 2006) there is still a lack of understanding of the elements that constitute a successful golf putt. Green reading (selecting correct initial ball direction), aim (placing putter face square to selected line), stroke and ball roll are the main biomechanical factors considered to contribute to a successful putt (Karlsen, Smith and Nilsson, 2008). One variable that has not been analysed extensively within the literature is the impact point on the golf ball.

Literature investigating the effect of impact point on the resulting kinematics of the golf ball during putting is limited. Cross and Nathan (2007) reported the gear effect (the rotation of the moving object around its centre of mass due to an off-axis impact) in ball collisions, including the golf ball. Results demonstrated the rate of spin increased when the angle of incidence (degree of deviation away from a perpendicular collision) is increased (Cross & Nathan, 2007), which could potentially be detrimental to putting performance by increasing the variability associated with the resultant putt. Cross and Nathan (2007) concluded that the gear effect occurs as a result of static friction between the ball and object during a collision. A clear limitation of the Cross and Nathan (2007) study is that during the experimental protocol, the ball was collided off a wooden block which is not as appropriate as the use of a putter. Alessandri (1995), Lorensen and Yamrom (1992), and Penner (2002) have all proposed mathematical models of the motion of a putted golf ball over the surface of the green.

More research is required to examine whether the impact point during the putter face – ball interaction influences the success of the subsequent putt. Additionally, many ball manufacturers choose not to include any performance information regarding putting, with predominant focus on driving distance and ‘soft’ feel during pitching and chipping. Raising the question as to whether dimple design negatively affects putting.

Currently no studies have investigated how variation in the impact point on the golf ball influences the resulting kinematics of the golf ball and, furthermore, how different dimple patterns on the ball can affect the kinematic variables of the shot. No method for the analysis of the effect of the impact point has been devised or suggested within the literature. Therefore, the aim of this study was to develop and assess the reliability of a method of locating a centroid location and identifying the impact point on a golf ball. If found to be reliable, it will allow for the method to be adopted and used in further research, such as determining whether the impact point on a golf ball has an effect on the resultant kinematics of the ball during the golf putt. It was hypothesised that the method of locating a centroid location and the two methods of identifying the impact point on a golf ball would be reliable.

Methods

Experimental set - up

All testing was completed on an artificial putting surface (Huxley Golf., Hampshire, UK) (3.66 x 4.27 m) registering 12 on the stimpmeter (The United States Golf Association., NJ, USA). A stimpmeter is a device used to measure green speed (initial ball velocity = 1.83 m/s, ball travelled 3.65 m). A mechanical putting arm mounted on an 360 kg bearing was set up to simulate a level 3.2 m putt, with a square to square swing path to ensure a square club face at impact. This refers to a single horizontal axis perpendicular to the putting line.

Two putters with different putter face characteristics (grooved or non grooved) were selected and used for the experiment. The GEL® (GEL GOLF., Wan Chai, Hong

Kong) Vicis putter (grooved face) had a 69º lie (angle formed by the shaft and sole of the putter head when the putter is in a neutral position) and 2.5º loft (angle formed by the putter face and level surface when the putter is in a neutral position), and the Odyssey (Callaway Golf Europe Ltd., Surrey, UK) White Hot #3 (non-grooved) had a 69º lie and 2.5º loft. Srixon (Srixon Sports Europe LTD., Hampshire, UK) Z-STAR golf balls and Titleist (Acushnet Europe Ltd., Cambridgeshire, UK) Pro V1 golf balls were used in the protocol. These particular golf balls were chosen due to them being two popular balls on the market, similar in construction and both brands premium offerings.

The golf balls were aligned using two Superline (Property Perspective Ltd, Warwick, UK) two-dimensional (2D) line lasers fixed to a 360˚ graduated base. One was placed directly behind the ball and the other was placed 90˚ to the path of the golf ball intersecting a visual putting aid printed on the ball. This split the golf ball into four equal sections ensuring the same position of the ball for each trial. A Canon (Canon Europe Ltd, Uxbridge, UK) EOS 1000d camera was situated on a stationary tripod in front of the line of the golf putt 2.5 m away from impact.

Procedure

The first putter was held securely in the mechanical putting arm and aligned using a swing path laminate and laser line to ensure a square to square swing path. The counterbalanced putting arm block was set to produce a putt of 3.2 m. The putting arm was attached to a weighted pole and released using an electromagnet to reduce friction to a minimum. Before the first trial was completed, a thin layer of pigmented emollient was applied to the face of the putter and smoothed out to confirm an even coating. This was repeated after every trial. The golf balls were aligned using the two Superline 2D line lasers fixed to a 360˚ graduated base as described in the experimental set – up.

After each trial a picture was taken (Canon EOS 1000d) with the ball placed 5 cm to the right of the original position before impact, angled to show the pigmented emollient imprint on the ball and the imprint of the dimple pattern left on the putter face. The ball was then cleaned of all pigmented emollient using an alcohol wipe and the next trial was completed. Each putter-ball combination had a total of 20 trials recorded (total 80 trials).

Data Processing

Determining the centroid location

Two 2D structures (Figure 1) were developed matching the Titleist and Srixon golf ball dimple patterns using Microsoft PowerPoint 2011 to locate the centroid (0, 0 coordinate of the dimple pattern). The Srixon golf ball had a single consistent size of dimple and therefore an equilateral triangle with a line drawn at every vertex fitted the dimple pattern identifying the centroid (0, 0 coordinate) of the three dimples (Figure 1 A). In contrast the Titleist golf ball had two sizes of dimple (Figure 1 B), one smaller dimple encapsulated by 5 larger dimples, so a pentagon with a line drawn at every vertex fitted the dimple pattern, identifying the centroid (0, 0 coordinate) of the six dimples.

[FIGURE ONE ABOUT HERE]

Scaling the picture

The photograph from each trial was exported into Adobe Photoshop CS5 (Adobe Systems Incorporated., CA, USA) and scaled using the known length of the GEL® and Odyssey putters hosel. The hosel was selected as it was flat on each of the putters and therefore was the most appropriate part to measure accurately.

The Photoshop ruler tool was used to calculate the angle that the ball was placed at. This was to confirm that the 2D structure was placed in the correct and same position, giving the same centroid (0, 0 coordinate) for each trial.

Calculating the centre of the impact area

To calculate the centre of the impact area or the impact point, a polygon was drawn at the four outermost edges of the impact area (Figure 2). The first edge was drawn horizontally from the two outermost edges and the angle was adjusted to the angle of the dimple pattern identified (Figure 2 A) when superimposing the 2D structure on the ball. This line was then copied and superimposed at the opposite outermost edge (Figure 2 B). These steps were repeated for the two vertical lines (Figure 2 C and 2 D). Each side was parallel to the opposite side and adjusted to fit correctly together. Generally this involved either lengthening or shortening the horizontal lines and this allowed for the polygon to be intersected from its four corners (Figure 2 E and 2 F) giving the centre point of the impact area.

[FIGURE TWO ABOUT HERE]

The Photoshop ruler tool was then used to measure the distance and angle of the impact point from the centroid of the dimple pattern, producing a measurable vector. Zero degrees were directly north of centroid. Additionally, the X and Y coordinates were measured from the centroid of the dimple pattern using vertical and horizontal guides. Pythagoras' theorem ($x^2 + y^2 = z^2$) was used to calculate the distance of the centre of the impact area to the centroid location to provide an alternative measurement technique to compare to the accuracy of the angle distance method.

Calculating the area of the impact zone

Scientific image processing software ImageJ (National Institutes of Health, Bethesda, Maryland, USA) was used to calculate the surface area of the impact area. The polygon selection tool was used to draw (at 0.5 mm intervals) around the impact area imprint on the golf ball (Figure 3) and gave an output of the surface area.

[FIGURE THREE ABOUT HERE]

Each putter-ball combination was processed and then reprocessed 24 hours later under the same conditions without reference to the previous analysis to keep the reliability testing blind.

Data Analysis

Data were exported to statistical software packages Microsoft Excel 2011 and SPSS v19 (SPSS Inc, Chicago, USA) for analysis. Reliability was assessed for the following variables: distance of the impact point from the centroid (distance from the centroid to the centre of the impact zone), angle of the impact point from the centroid (the angle of the centre of the impact zone from the centroid), X coordinate from the centroid, Y coordinate from the centroid and the resultant distance from the centroid (using the X, Y coordinates and the following formula: $x^2 + y^2 = z^2$). To ensure unbiased results, the test-retest analysis was completed blind, without reference to the other days analyses.

The data were found to be normally distributed using a Shapiro – Wilk test for normality. A combination of descriptive (mean ± SD and change in mean ± 95% confidence limits (CL) (expressed as a percentage) and reliability statistics were used. The change in mean and 95% CL stipulated an indication of absolute variation between the data sets.

Reliability statistics were the standard error of measurement expressed as a percentage (SEM%) (formula: $SEM = SD\sqrt{1 - ICC}$), a two – way mixed intraclass coefficient (ICC) (formula: $\frac{1-SD\^2}{SD\^2}$ were used.) (Hopkins, 2000) and a Cohen's repeated measures effect size (ES). The boundaries set for the coefficient statistics were; *r* = 0.8 – 1.0, very strong, *r* = 0.6 – 0.8, strong, *r* = 0.4 – 0.6, moderate, *r* = 0.2 – 0.4, weak, *r* = 0.0 – 0.2, no relationship (Salkind, 2011). In accordance with Saunders, Pyne, Telford and Hawley (2006) ES were interpreted as < 0.1 as trivial, 0.1 – 0.6 as small, 0.6 – 1.2 as moderate and > 1.2 as large. Assessing these statistics as a collective group will provide a clear impression of the relibiability and reproducibility of the method. For a reliabiltiy rating of 'excellent' the criteria threshold was change in mean < 5%, ICC > 0.90, SEM% < 10% and ES < 0.60. For 'good' reliability, all but one criteria had to be met, for 'moderate' reliability all but two criteria had to be met, and 'poor' reliability was defined as three of the criteria not being met (Joseph, Bradshaw, Kemp & Clark, 2013).

Results

Overview of reliability

Tables 1 to 4 present descriptive and reliability statistics for the impact varibles. Reliability was catagorised as excellent for all combined putter-ball combinations for each of the four impact variables. When putter-ball combinations are considered separately, the lowest reliability category demonstrated was good (the only failed criteria was the ES).

Surface Area

Surface area results (Table 1) noted excellent – good reliability catagories between the four putter-ball combinations. The SEM% for all four putter-ball combinations between Test 1 and Test 2 were < 3.3% (<1 mm^2 when considered as a raw number) and the ICC values demonstrated very strong reliability for the combined group and individual putter golf ball combintations (ICC = 0.95 – 0.99). For the three putter-ball combinations that were catagorised as demonstrating good reliability, the ES was the criteria that was broken. The largest change in mean % scores were observed for the Odyssey-Srixon combination at 3.2%. The 95% CL was consistent across groups ranging from 2.7 – 3.0%. At first glance, this variance may look relatively large, however, when considered with the change in mean percentage the largest variance between means was 6.1%. This does emphasise the fact that care is needed when processing the images for surface area.

[TABLE ONE ABOUT HERE]

Distance of impact point from the centroid location

The combined putter-ball combinations demonstrated excellent reliability for the distance of the impact point from the centroid location impact variable, this was apparent for the individual putter-ball combinations apart from the GEL®-Titleist group (Table 2). The ICC was consistently very strong (ICC = 1.00) and was coupled with consistently low SEM% values (1.6 – 2.9%). The change in mean percentage were consistently low across all four combinations along with the 95% CL. Again, the ES was the failed criteria for the GEL®-Titleist combination, catagorising the reliability as good.

[TABLE TWO ABOUT HERE]

Distance of the impact point from the centroid derived from the X, Y coordinates

Distance data derived from the X, Y coordinates (Table 3) demonstrated excellent reliability across the putter-ball combinations except from the GEL®- Srixon combination which was catagorised as good (SEM% = 1.6 – 3.2%; ICC = 0.99 – 1.00). Descriptive statistics reassert the excellent reliability demonstrated, no irregularities were observed for any data set. The SD remained consistant for all groups across all trials, suggesting the variability observed actually existed rather than being an analysis error.

When comparing the two methods to measure the distance from the centroid location the distance (measured directly) and angle method had a SEM% range of 1.6 – 2.9%, when dirived from the X, Y coordinates the SEM% range was 1.6 – 3.2%. Therefore, the distance from the centroid when measured directly, demonstrated marginally better absolute reliability, but when the differences in SEM% are insignificant, both methods can be considered reliable at measuring the impact point. A general trend identified that the distance derived from the X, Y coordinates were slightly shorter than that when directly measuring the impact point from the centroid, but the differences were minimal and did not increase as the distance from the centroid increased. Therefore as long as one method is chosen and all trials are analysed using the same procedure, both methods could be used to calculate the distance of the impact point from the centroid.

[TABLE THREE ABOUT HERE]

Angle of the impact point from the centroid location

Reliability was categorised as excellent for all putter ball combinations except from the Odyssey-Titleist combination which was catagorised as good (failing the ES criteria for inclusion to excellent reliability) (Table 4). This was particularly reflected in very low SEM% (0.9 – 4.3%) and very strong ICC scores (0.98 – 1.00) showing very strong relationships between Test 1 and Test 2. Descriptive statistics confirm very strong reliability with no apparent anomalies for the combined data set or individual putter-ball combinations, with consistent SD observed.

[TABLE FOUR ABOUT HERE]

Discussion and Implications

The aim of this study was to test the reliabilty of a method to identify the impact point on a golf ball. This would allow for further analysis to see the effect on resultant ball roll kinematics. It was hypothesised that the two methods calculating the distance and direction of the impact point from the centroid would be reliable, this can be accepted. The methods were the manual measurement of the distance coupled with the angle from the centroid location and measuring the X, Y coordinates and calculating the distance of the impact point from the centroid. The results for both methods were reliable, therefore both methods are appropriate for future analysis. It was the preference of the authors to use the distance angle measurement, over the X, Y coordinates method. Additionally, this method allows for increased statistical power during multiple regression analysis, due to reducing the number of independent variables by one. Therefore this method can be considered suitable to evaluate the effect of the impact point on the subsequent kinematics of the golf ball.

It is worthy noting that greater variability for angle from the centroid location (Table 4) (as reflected in the SEM%) was observed in the Srixon ball in comparison to the Titleist ball when hit with the GEL® putter. This could potentially reveal that certain styles of putters (grooved faced/traditional faced) demonstrate more consistency when used in conjunction with certain brands of balls with differing dimple patterns.

It is difficult to draw comparisons to other methods that identify and analyse the impact point on a golf ball, as currently within the literature the variable has been overlooked. Research by Brouillette and Valade (2008), Brouillette (2010) and Hurrion and Hurrion (2008) has been limited to analysis of the roll of the golf ball, with no discussion of the effect of the impact point. This is also apparent in studies (Alessandrini 1995; Lorensen & Yamrom, 1992 and Penner, 2002) that have used mathematical models to predict the roll of the golf ball. Karlsen et al. (2008) state that impact point accounts for 3% of direction variability, however, they only tested impact from the sweet spot in comparison to horizontal miss-hits and not the variability observed within each impact type, therefore this claim may be unsubstantiated.

A potential limitation of this study is that there is no obvious criterion measure that this method can be compared to. Therefore the validity of this method cannot be tested. Additionally, some researchers may demonstrate more subjective variability and less accuracy (in undertaking the method to locate the centroid location and subsequent impact point). To ensure reliability of future analysis using this method, it is suggested that a pilot analysis is undertaken before the main analysis. This is to certify that there is minimal variablilty during the data processing. By demonstrating very strong relative and absolute reliability, it shows that in this study the researcher was consistently accurate in identifying all variables.

Conclusion

Good to excellent reliability was demonstrated for all impact variables when the reliabilty statistics were interpreted as a collective group during analysis of the experimental method to determine the impact point of the putter on the golf ball. All variables had very low SEM% and demonstrated very strong relative reliability (ICC = 0.95 – 1.00). This method can be considered reliable in the assessment of the point of impact on the golf ball. Therefore, the method can be used for subsequent analysis of the effect of variation in the impact point on the golf ball on subsequent ball roll kinematics. Care needs to be taken during the entire data processing method, due to the high number of stages involved in the image processing protocol. If an error is made during one stage it will ultimately effect the subsequent stages, therefore reducing relative and absolute reliability. It is suggested that all researchers test the reliability to eliminate variance in subjectivity before main analysis (assessing whether impact point affects putting direction variability) takes place.

References

Alessandrini, S. M. (1995). A motivational example for the numerical solution of two-point boundary-value problems. *SIAM review*, *37*(3), 423-427.

Brouillette, M. (2010). Putter features that influence the rolling motion of a golf ball. *Procedia Engineering, 2*(2), 3223-3229.

Brouillette, M., & Valade, G. (2008). The effect of putter face grooves on the incipient rolling motion of a golf ball. In: Crews, D., & Lutz, R., editors*. Science and golf V: Proceedings of the World Scientific Congress of Golf.* Mesa, Arizona: Energy in Motion; pp. 363-368.

Cross, R., & Nathan, A. M. (2007). Experimental study of the gear effect in ball collisions. *American Journal of Physics*, *75*, 658.

Dorsel, T. N., & Rotunda, R. J. (2001). Low scores, top 10 finishes, and big money: An analysis of professional golf association tour statistics and how these relate to overall performance. *Perceptual and Motor Skills, 92*(2), 575-585.

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Medicine, 30*(1), 1-15.

Hurrion, P. D., & Hurrion, R. D. (2008). An investigation into weight distribution and kinematic parameters during the putting stroke. In: Crews,D., & Lutz, R., editors. *Science and golf V: Proceedings of the World Scientific Congress of Golf.* Mesa, Arizona: Energy in Motion; pp. 223-238.

Joseph, C. W., Bradshaw, E. J., Kemp, J., & Clark, R. A. (2013). The Interday Reliability of Ankle, Knee, Leg, and Vertical Musculoskeletal Stiffness During Hopping and Overground Running. *Journal of Applied Biomechanics*, *29*(4), 386-394.

Karlsen, J., Smith, G., & Nilsson, J. (2008). The stroke has only a minor influence on direction consistency in golf putting among elite players. *Journal of Sports Sciences, 26*(3), 243-250.

Lorensen, W. E., & Yamrom, B. (1992). Golf green visualization. *IEEE Computer Graphics and Applications*, 12(4), 35-44.

Pelz, D. T. (2000). *Dave Pelz's Putting Bible*. New York: Random House.

Penner, A. R. (2002). The physics of putting. *Canadian Journal of Physics, 80*(3), 83-96.

Quinn, R. J. (2006). Exploring correlation coefficients with golf statistics. *Teaching Statistics, 28*(1), 10-13.

Salkind, N. J. (2011). Statistics for People who (Think They) Hate Statistics. Portland: Sage.

Saunders, P. U., Telford, R. D., Pyne, D. B., Peltola, E. M., Cunningham, R. B., Gore, C. J., & Hawley, J. A. (2006). Short-term plyometric training improves running economy in highly trained middle and long distance runners. *The Journal of Strength & Conditioning Research*, *20*(4), 947-954.

Wiseman, F., & Chatterjee, S. (2006). Comprehensive analysis of golf performance on the PGA tour: 1990-2004. *Perceptual and Motor Skills, 102*(1), 109-117.

Table 1. Reliability of the impact variable surface area for the combined data set and individual putter-ball combinations.

	Test 1 (mm^2 ± SD)	Test 2 (mm^2 ± SD)	Change in Mean ± 95% CI (%)	ES	SEM%	ICC	Reliability
Odyssey-Srixon	27.40 ± 2.79	26.55 ± 3.32	3.2 ± 2.9	1.23	2.9	0.95	Good
Odyssey-Titleist	22.21 ± 3.26	21.79 ± 3.10	1.9 ± 3.0	0.76	3.0	0.97	Good
GEL®-Srixon	21.83 ± 4.05	21.86 ± 3.71	0.2 ± 2.7	0.05	2.6	0.98	Excellent
GEL®- Titleist	19.57 ± 5.19	20.19 ± 5.21	3.1 ± 2.7	0.97	2.6	0.99	Good
Average	22.75 ± 4.76	22.60 ± 4.47	0.7 ± 1.5	0.23	3.2	0.98	Excellent

Table 2. Reliability of the impact variable distance from the centroid location for the combined data set and individual putter-ball combinations.

	Test 1 (mm ± SD)	Test 2 (mm ± SD)	Change in Mean ± 95% CI (%)	ES	SEM%	ICC	Reliability
Odyssey-Srixon	1.56 ± 0.73	1.57 ± 0.73	0.6 ± 2.6	0.43	2.6	1.00	Excellent
Odyssey-Titleist	2.86 ± 0.80	2.86 ± 0.80	0.0 ± 2.1	0.00	2.1	1.00	Excellent
GEL®-Srixon	1.37 ± 0.57	1.36 ± 0.59	0.7 ± 2.9	0.55	2.9	1.00	Excellent
GEL®-Titleist	2.51 ± 0.91	2.53 ± 0.90	0.8 ± 1.6	0.70	1.6	1.00	Good
Average	2.08 ± 0.97	2.08 ± 0.97	0.0 ± 1.0	0.00	1.9	1.00	Excellent

Table 3. Reliability of the impact variable distance derived from the X, Y coordinates from the centroid location for the combined data set and individual putter-ball combinations.

	Test 1 (mm ± SD)	Test 2 (mm ± SD)	Change in Mean ± 95% CI (%)	ES	SEM%	ICC	Reliability
Odyssey-Srixon	1.53 ± 0.72	1.54 ± 0.73	0.7 ± 2.0	0.44	2.0	1.00	Excellent
Odyssey-Titleist	2.86 ± 0.81	2.82 ± 0.79	1.4 ± 3.2	0.50	3.2	0.99	Excellent
GEL®-Srixon	1.32 ± 0.57	1.34 ± 0.59	1.5 ± 3.0	1.09	3.0	1.00	Good
GEL®-Titleist	2.49 ± 0.89	2.50 ± 0.90	0.4 ± 1.6	0.35	1.6	1.00	Excellent
Average	2.05 ± 0.98	2.05 ± 0.97	0.0 ± 1.0	0.00	2.0	1.00	Excellent

Table 4. Reliability of the impact variable angle from the centroid location for the combined data set and individual putter-ball combinations.

	Test 1 (° ± SD)	Test 2 (° ± SD)	Change in Mean ± 95% CI (%)	ES	SEM%	ICC	Reliability
Odyssey-Srixon	137.4 ± 33.4	137.1 ± 33.8	0.2 ± 0.9	0.09	0.9	1.00	Excellent
Odyssey-Titleist	150.6 ± 11.2	151.4 ± 11.2	0.5 ± 0.9	0.71	0.9	0.99	Good
GEL®-Srixon	108.3 ± 51.6	105.7 ± 48.6	2.4 ± 4.4	0.52	4.3	0.99	Excellent
GEL®-Titleist	134.8 ± 9.9	135.1 ± 9.8	0.1 ± 1.1	0.22	1.1	0.98	Excellent
Average	132.8 ± 34.2	132.3 ± 33.8	0.4 ± 0.9	0.15	2.0	0.99	Excellent

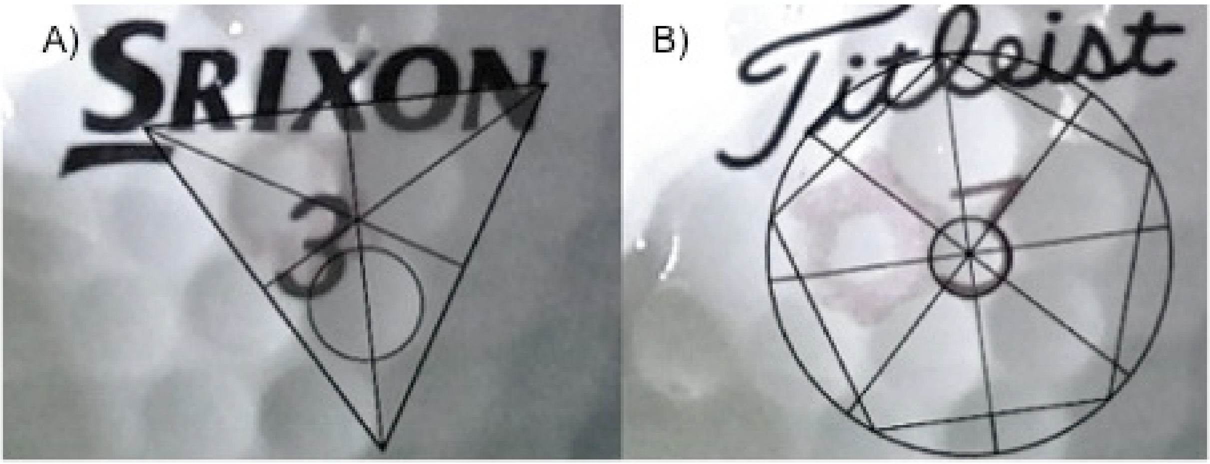

Figure 1. Two polygon structures developed to identify the centroid of the A) Srixon and B) Titleist golf ball.

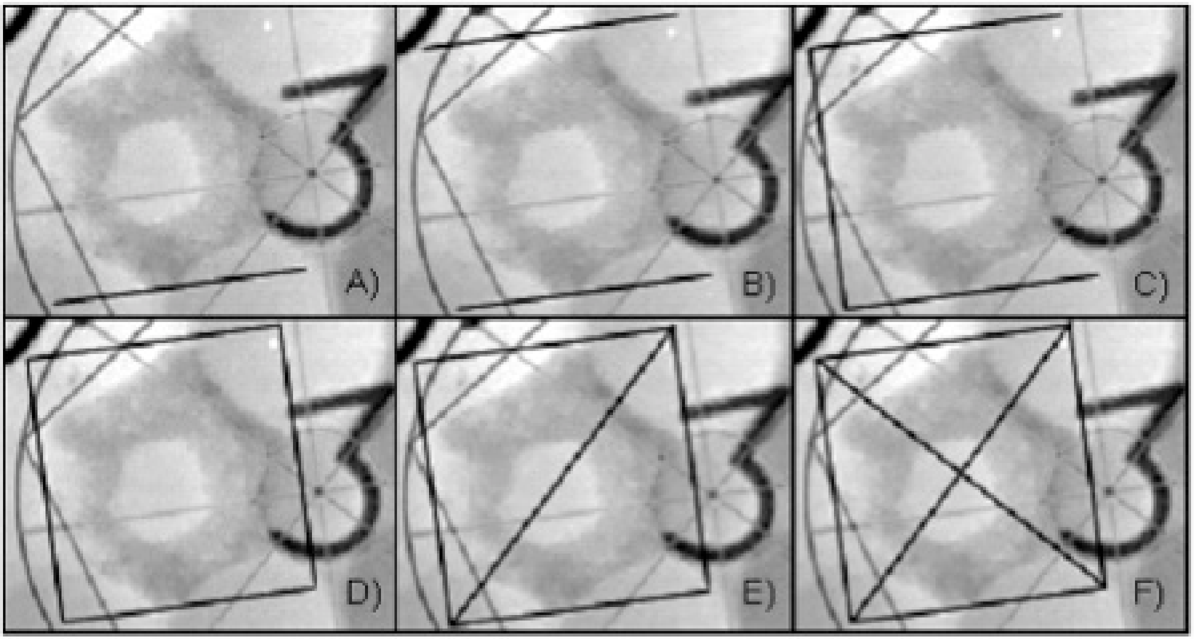

Figure 2. Step by step process of constructing and intersecting a polygon to identify the coordinate of the impact point.

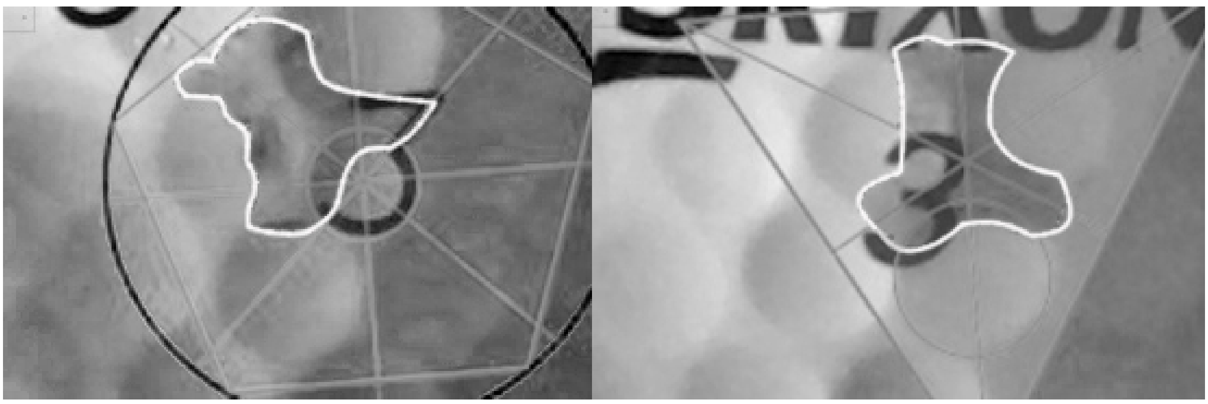

Figure 3. Titleist and Srixon golf balls with the polygon outline for calculation of the impact area.