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The effect of skid distance on distance control in golf putting

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Abstract

In putting, a common assumption is made that a performance improvement will be made when the ball begins to roll more quickly following the impact with the club. Previous research has reported that distance control accounts for 80% of putting performance. Other research has claimed that maximum percentage of roll in a putt will increase predictability and accuracy; however, this has never been directly studied. An experimental study was conducted to investigate the relationship between putter loft angles, roll ratio, and distance control on both an artificial putting turf surface and natural putting green. Four identical blade putters with different loft angles (-1, 1, 3, 5 degrees) were tested using a high speed camera and a mechanical putting machine to determine the skid length of a large number of putts. The final ball position was recorded to ascertain the distance variability of each club at each putt length and quantify each club's roll ratio. A ball ramp was used to quantify the variability attributed to the putting surface. The roll ratios of each club were found to be significantly different from each other ($p<0.05$) with the exception of the three and five degree putters. The negatively lofted putter in this study showed the greatest roll ratio and most consistent final distance. Recommendation of negative delivered loft could lead to changes in putter fitting philosophy.

Selection and peer-review under responsibility of the Centre for Sports Engineering Research, Sheffield Hallam University

Keywords: Golf Putting; Skid Distance; Roll Ratio; Distance Control; Contact Time; Loft Angle

1. Introduction

Putting is the most prevalent of all golf shots accounting for nearly half of all shots taken as reported by Pelz (2000), Riccio (1990) and Cleaver (n.d.). Putting has been proven by Alexander and Kern (2005) as the most important single type of shot in a golfer's game in a study relating professionals' earnings to putting performance. If the putter can be optimised to increase performance of a putt, a golfer can gain an advantage in a very important aspect of the game.

Many studies have been done to analyse the interaction between the ball-green and the ball-putter. Daish (1972) described the motion of a putt dividing it into two phases, skidding and rolling. He defined the skidding phase as any 'mis-match' of the translational and peripheral speed of the ball, whereas rolling occurs when the two

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speeds are equal. Skidding occurs until the torque acting on the ball from frictional forces increases the spin rate to match the translational speed of the ball. Studies by Daish (1972), Rojas and Simon (n.d.), and Cochran and Stobbs (1986) have mathematically estimated that rolling will occur at about 70% of the initial speed of the ball, and the skid distance accounts for about 20% of the putt length. Models by Alessandrini (1995) and Penner (2003) have been created assuming pure rolling motion for the entirety of the putt, however, more valid models by Perry (2002) and Lorensen and Yamrom (1992) have accounted for skidding effects. These models made the assumption that contact between the ball and the surface was maintained for the duration of the putt. It has been reported by Daish (1972) and Lindsay (2003) that during a putt the ball progresses in shallow bounces due to green irregularities. These irregularities cause inconsistencies in putts especially in the skidding phase as indicated by Aldrich (2004), Karlsen and Nilsson (2008), and Matlby (n.d.).

A common assumption is pointed out by Maltby (n.d.), Chou (2004), and Swash (n.d.) that minimising the skidding distance in a putt will help achieve greater putting performance. The design of the club has been looked at to achieve rolling sooner. A cylindrical style putter has been purported by Daish (1972) and Gwyn et al. (1996) to reduce skidding in a putt. A 'ping' style putter with a low centre of gravity utilising the vertical gear effect has also been looked at with interest by Daish (1972), Lindsay (2003), and Cross (2006) as an optimal design to minimise skidding. Certain face treatments to putters have been reported by Aldrich (2004) and Hurrion and Hurrion (2002) to lessen skidding, but these claims contradict a study by Brouillette (2010) that found face treatments to have no effect on initial spin characteristics. Dynamic loft angle of the putter face has been discussed by Lindsay (2003), Chou (2004), and Butdee and Punpojmat (2007) as the important feature in minimising skid distance due to a degree of back spin imparted on the ball at impact. Thus, fitting a putter to an optimised dynamic loft is crucial to minimising skid length.

As a ball is hit harder it will take more time for skidding to cease and rolling to commence even though the ball's movement takes much more time. It would be more effective to classify a putt's skid as a 'Roll Ratio' defined by Equation 1 rather than a distance or a time. This value may be able to be applied to a particular putter/player combination and should hold for all putts.

$$Roll\ Ratio = \frac{Total\ Putt\ Length - Skid\ Length}{Total\ Putt\ Length} \tag{1}$$

Claims that minimised skidding distance in a putt will lead to increased control and performance have been made but never directly studied. There is also a common understanding that skidding creates inconsistency in a putt, but this has never been directly measured. The aim of this research was to investigate the relationship between putter loft angles, roll ratio, and distance variability on an artificial turf putting surface and a natural putting green.

2. Methods

2.1 Materials and Testing

Four PING Karsten 1959 Anser putters with different loft angles (-1, 1, 3, and 5 degrees) were tested using a bespoke mechanical putting rig (see Figure 1). The putters were pulled back to a fixed position of the gravity driven pendulum arm, and putt speeds (measured by high speed video) were found to be highly repeatable (n=30, 0.875 ± 0.007 m/s). Each putter performed 15 trials at each of the five different putt lengths between 0.9 and 4.6 m. Each putt was struck at the neutral position of the pendulum, translating to a neutral attack angle and shaft lean. Two Leica DISTO D2 laser measures with a separation of 2.00 m were used to triangulate the final position of the ball providing the putt length. The trials were filmed using a Phantom V4.3 high-speed camera positioned orthogonal to the plane of motion at 1000 Hz. Calibration was performed using an object of known dimensions in the plane of motion of the golf ball.

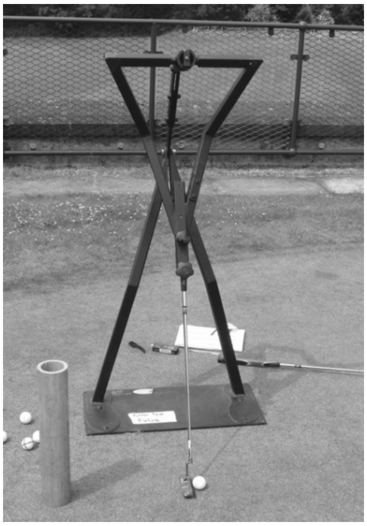

Fig. 1 Bespoke mechanical putting rig

2. 2 Data Analysis

The high-speed video was analysed using bespoke software developed by Sheffield Hallam University. The centre of the ball was digitised to determine the translational position of the ball. A point on the periphery was also digitised to determine the angular position of a single periphery point on the ball. The angle of the periphery point for a given time was calculated using an inverse tangent function.

The translational ball speed and periphery point speed were calculated using the derivatives of cubic function trend lines fitted to the positional and angular data with respect to time. Rolling was deemed to occur at the time the translational and periphery ball speeds were equal. The corresponding distance of the ball at this time was considered the skid distance; the roll ratio was then found with Equation 1.

A Shapiro-Wilk Test was used to assess the Gaussian distribution of each of the roll ratio data sets, and the data were normally distributed. A one-way analysis of variance with a Tukey post hoc test was used to assess any difference in the means of roll ratios. Confidence intervals of 95% were assumed for significance.

In order to assess the surface variability, a ball ramp was used to launch balls in a pure rolling state as previously implemented by Karlsen and Nilsson (2008) and Koslow and Wenos (1998). Fifteen trials were performed at each of the nine targeted distances between 0.9 and 4.6 m. For each targeted distance the ball was launched at the same position on the ramp (repeatable to (n=33) 1.167 ± 0.007 m/s). The ramp was positioned to launch the ball at the same location with the same direction as the mechanical putting rig. The final ball position was recorded for each of the trials. This provided a baseline measure of the degree of inherent distance variability caused by surface inconsistencies. The distance variability for each group of data, rolling and putted, was assessed using the variance. The initial launch conditions, including ball speed and spin, were also evaluated.

The roll ratio and distance variability testing was performed on an artificial turf surface (pile height = 0.01 m) and a natural putting green surface (blade length = 0.01 m) at Gainsborough Golf Club, UK. The speeds of the surfaces were assessed by following the guidelines for using a Stimpmeter set by the USGA (n.d.). The protocol was carried out three times on the natural turf surface to account for any fluctuation in the speed throughout the day of testing. Speeds of the putting surfaces were reported as a distance in accordance with the USGA guidelines, with a greater distance relating to a faster surface. Inherent errors of testing on a natural green included difficulty in finding a surface that was naturally level, had uniform grass consistency, and had minimal imperfections. As the trials were performed for each set, an impressed path on the surface was noticed from the ball moving over the same area. After each set was completed, the surface was brushed to reduce any additional inconsistencies.

3. Results

Figure 2a displays the mean roll ratios observed for each putter on each of the given surfaces. In post hoc analysis each club was found to be significantly different from each other ($p<0.05$) on each surface with the exception of the difference between the three and five degrees putters ($p>0.05$). The initial spin rates of the putts are given in Figure 2b. The distance variability of each of the clubs on the different surfaces along with the inherent surface variability is displayed in Figure 3. The average Stimpmeter speed of the natural turf was found to be 2.51 m, which fluctuated only 0.03 m throughout the day, and the Stimpmeter speed of the artificial turf surface was 2.61 m. These speeds related to a medium paced green as per USGA guidelines (n.d.).

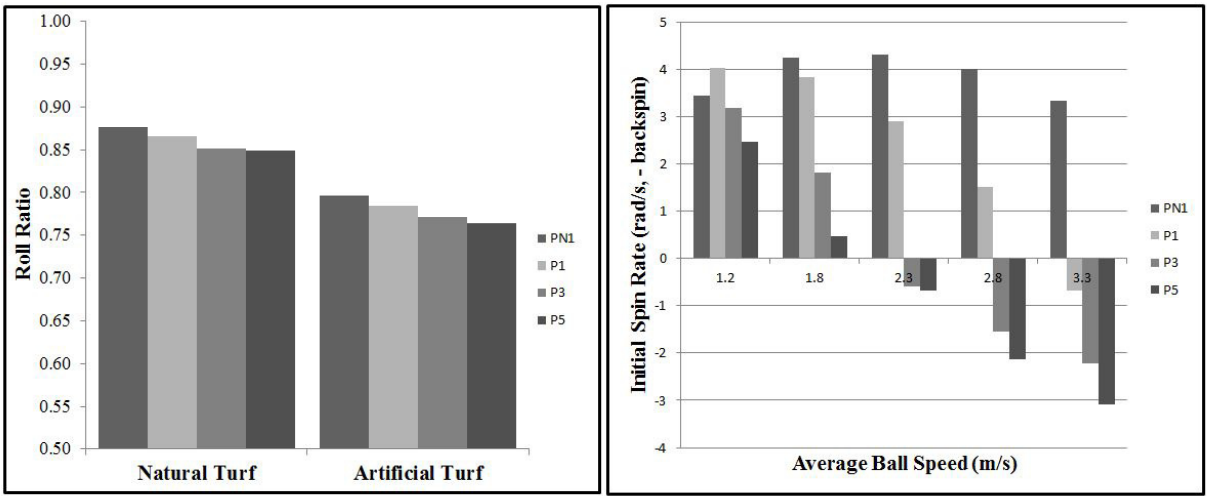

Fig. 2 Mean roll ratios (a) Mean initial spin rates of the putts at the five different putting speeds. Backspin is negative (b)

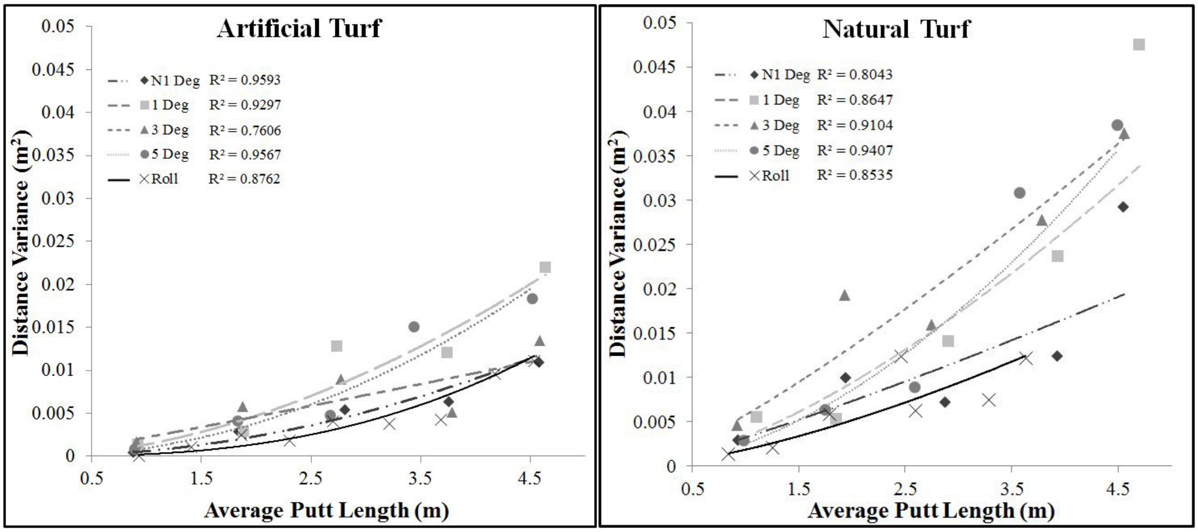

Fig. 3 Distance variance on artificial turf (a) and natural turf (b)

4. Discussion

Testing on the artificial turf surface and the natural putting green yielded an increased roll ratio as the loft of the putter decreased as seen in Figure 2a. The roll ratios were greater on the natural turf than artificial turf, likely due to a greater coefficient of kinetic friction. It was theorised that an increased roll ratio would return greater distance control, i.e. less distance variability; however, the results shown in Figure 3 did not follow this conjecture.

There is no clear pattern directly relating the roll ratios to a distance variance measurement. However, on both surfaces the negatively lofted putter produced the most consistent distance variation of all the lofts tested. The rolling condition was utilised to produce a base measure of the surface in order to isolate the variance produced from skidding alone. This condition produced the least amount of distance variation compared to any of the putted balls. These rolling data sets not only provided the amount of variation due to the surface alone, but also provided compelling evidence that a rolling ball is more consistent. This supports widely held assumptions that a putt that rolls for a greater ratio of its length is more desirable for distance control.

The natural turf results displayed a trend of increased variability as putt length increased with positively lofted putters. The negatively lofted putter did not follow the same trend and followed the progression of the rolled trials. A longer putt requires a greater impact speed from the putter head, thus amplifying effects of the loft on the launch and the initial spin rates. The difference in variability trends between the negatively and positively lofted putters was attributed to the ball being launched to a greater height with a greater backspin due to the degree of loft of the putter face. In Figure 2b, a trend is noticed relating the amount of loft and putt speed to the amount of backspin imparted to the ball. As loft increases above zero, the amount of backspin increases. Likewise, as the initial putt speed increases, the amount of backspin increases. An increase in the amount of backspin effectively increases the amount of skid and decreases the roll ratio by increasing the differential between peripheral ball speed and translational ball speed.

In this study the negative one-degree putter produced the greatest roll ratio and distance control especially as putt length increased. This study delivered the putter head to contact the ball with a neutral rise angle and shaft lean, which effectively equalised the static loft angle and the dynamic loft angle. It has thus been shown that increasing the delivered loft was commensurate with decreased roll ratio. The negatively lofted putter produces a putt that is not launched into the air thus initiating contact with the ground sooner. This earlier frictional component, combined with less backspin, which induced the rolling phase earlier, was found to achieve the most consistent putts in terms of distance control.

With a human golfer, neutral rise angle and shaft lean rarely occurs. A human will likely always have some degree of shaft lean and rise angle in a putt. The majority of the golf industry currently adapts putters to achieve initial launch conditions of approximately one to four degrees. This research suggests altering the fitting philosophy to recommend delivered loft to be neutral or negative degrees. Hesitation may exist in fitting to negative delivered loft due to the fear of driving the ball into the turf or not getting the ball up on top of the blades of grass. However, these results provide evidence supporting negative delivered loft by increased roll ratio and thus distance control.

5. Conclusion

This study found a negative one-degree lofted blade putter to perform better than one, three, and five degree putters with a neutral rise angle and shaft lean. This evidence could lead to the putter fitting process to adopt idealising negative to neutral delivered loft. Although trends in the distance variability were observed, more extensive testing could yield more consistent patterns in each club's performance. Future studies should extend the range of putts to encompass the effects of longer putts, and implement more loft angles specifically between two degrees and negative three degrees to find the optimal putter loft angle. Additional testing utilising players would provide pragmatic evidence to support claims made in this paper.

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