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A DYNAMIC EVALUATION OF HOW KICK POINT LOCATION INFLUENCES SWING PARAMETERS AND RELATED LAUNCH CONDITIONS

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1.0 Abstract:

In golf, many parameters of the driver can be modified to maximise hitting distance. The main objective of this study was to determine whether drivers fitted with shafts having high and low kick points would alter selected swing parameters, and related launch conditions. Twelve elite male golfers (handicap 1.2 ± 1.8) had three shots analysed for two drivers fitted with “stiff” shafts with differing kick point location. Stiffness profiles of these shafts were also measured. Five swing and related launch parameters were measured using a real-time launch monitor. The locations of the low and high kick points on each shaft during the golf swing (the dynamic kick points) were confirmed via motion analysis. The driver fitted with the shaft containing the high kick point displayed; a more negative (steeper) angle of attack ($p<0.01$), a lower launch angle ($p<0.01$) and an increased spin rate ($p<0.01$) when compared to a driver fitted with a low kick point shaft. It is possible that the attack angle differed between-driver due to the greater amount of shaft bending found late in the downswing (80% of the downswing and just before impact). Future work is needed in this under-researched area to determine why these differences occurred.

2.0 Introduction:

In golf, driving ability consists of driving distance and driving accuracy and is associated with lower overall score [1-3]. Technique factors, such as the so-called “X-factor” which is defined as the angular displacement between the pelvis and shoulders [4-6], and equipment factors such as the shaft of the driver, may influence driving distance. Shaft properties can be altered to help optimise swing parameters and related launch conditions [7-10]. These properties include; shaft length (which may only be altered within a certain range), shaft stiffness, shaft mass, location of the point of maximum bend (kick point) and the distribution of mass in the shaft, and can influence parameters such as centre of mass and moment of inertia.

Researchers [11-13] have claimed that shaft stiffness influences swing parameters, for example, increased stiffness may lead to higher clubhead speed at ball impact [13]. However, determining shaft stiffness is a complex issue. Probably, the most commonly used description of shaft stiffness in the golfing market is stiffness grading (e.g. ladies, amateur, regular, stiff, extra stiff). However, no industry standards exist for these categories [14-15]. To address this problem, flexural rigidity (EI) testing may be used as a more comprehensive method to determine shaft stiffness. The EI profile of a shaft depends on its modulus of elasticity (E) and its cross sectional area (I) and EI values for a shaft will change along its length [15-16]. This method should be utilised in this area of research.

Researchers have postulated that shaft mass influences swing parameters and related launch conditions such as launch angle of the ball [7,17]. However, as with shaft stiffness, despite quantitative values for actual shaft mass, manufacturers also use alpha-numeric values to describe the distribution of mass [18]. There are two moments of the shaft with the first being about the wrist-cock axis (termed the swingweight) and the second being the moment of inertia about the club's centre of mass [19]. A driver's swing-weighting is related to the 'feel' of the club and is quantified alpha numerically within the range C9 to D8, with each swingweight equivalent to 'two inch-ounces' [20]. Further, swing-weight is related to the distribution of mass about a fulcrum point which is a known distance from the butt of the shaft, such that heavier shafts have a higher swing-weighting [18]. However, a club's swingweight is not a good predictor of clubhead speed, and shows no correlation with dynamic performance [8,17,18,20].

The location of the kick point is typically determined in a static manner by applying a known load to the tip of the shaft and finding the maximum perpendicular distance between the bent shaft and a line joining the shafts two ends when not bent [20]. From previous work examining elite golfers [7,17], the static kick point may be located anywhere between 44–60% of shaft length (when expressed from the club's tip). However, the golf swing is a highly dynamic movement and motion analysis [8-9, 15,21-22] and computer simulation [8,23-24] have suggested that the dynamic bending profile of a golf club differs to that determined under static conditions. Despite claims that clubs with higher kick points tend to produce lower ball launch angles [17,25], little experimental evidence has been provided. Further, to our knowledge no research has examined whether kick point location affects swing parameters and related launch conditions such as clubhead speed and launch angle. Other important related issues include the magnitude of bending of the shaft in the downswing as shaft bend and the timing of it, will determine the presentation of the clubhead to the ball [19,26]. A higher swing speed is also known influence the amount of shaft bending [27].

The first of three aims of this study was to determine whether changes in the location of the kick point of a driver caused differences in clubhead speed and attack angle (swing parameters), and indirectly influenced ball velocity, launch angle and spin rate of the ball (related launch conditions). The second aim was to determine whether significant associations existed between the swing parameters and their related launch conditions for each driver. The final aim was to determine whether the kick point location influenced the amount of shaft bend throughout the downswing.

3.0 Methods:

3.1 Participants and Experimental Protocol

Twelve right-handed high level amateur male golfers (mean ± SD; age 24.7 ± 6.0 years, handicap 1.2 ± 1.8 score) were recruited based on the following criteria; being a male aged between 18-35 years and having a registered golfing handicap ≤ 5. All participants were informed of the research procedures and informed consent was given by all participants prior to testing. Permission to conduct the study was provided by the Institutional Human Research Ethics Committee. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

This study utilised a repeated-measures design. Each participant hit six shots with each of two drivers (i.e. 12 shots) that were fitted with interchangeable shafts of the same broad stiffness grading ("stiff") but with differing kick point locations. While professional golfers may have the kick point location customised for their clubs [7,15], in this study it was not feasible to change kick point location without also modifying the shaft mass. A 56 g “stiff” shaft, termed the shaft with a low kick point, and a 78 g “stiff” shaft, termed the shaft with a high kick point, were utilised in this study. The drivers had identical grips, heads and club length, and were typically used by elite-level male golfers. The static kick point was defined as the point of maximum deflection along the shaft from a vector-line created between the end of the grip and the tip of the shaft, when a 2.3 kg load was suspended from the tip. The static kick point of both shafts had been located using an opto-electronic motion analysis as described elsewhere [22].

A professional club-fitter performed the relevant testing methods to obtain the other properties of the two shafts (Table 1). Shaft stiffness was measured using a shaft frequency analyser which measured the oscillations in cycles per minute when a perturbation was applied. Torsional stiffness was determined by measuring the angular displacement of the shaft while a known torque was applied. The shaft was clamped at the butt end during these first two procedures. Next, the swingweight of each driver was measured with the shaft balanced at a fulcrum point at a known distance from the butt end. The required swingweight to achieve balance was added, with the heavier shaft showing a higher swing-weight. Finally, the moment of inertia about the centre of mass was determined using the Auditor MoI speed match system (Golfmechanix, Taiwan) which measures the amount of resistance to motion about a fixed axis on the shaft.

INSERT TABLE 1 ABOUT HERE

After a standardised warm up which included five familiarisation swings with each driver, each participant hit their 12 shots from an artificial turf surface into a net positioned 5 m in front of them. Participants were instructed to hit the golf ball as straight as possible using their full, normal swing. To eliminate potential bias, shot order was block-randomised (i.e. all shots were hit with either driver in a blocked format) and participants were blinded to the drivers they were using. This was done by covering any visual markings on each shaft. Selected swing parameters and their related launch conditions were measured using a real-time launch monitor. To confirm that the kick points evaluated in a static manner would still be considered as high (78 g shaft) and low (56 g shaft) when determined from dynamic evaluation (i.e. during the golf swing), the opto-electronic motion analysis system was used to determine the location of the dynamic kick point. Three of the six shots from each driver were utilised for further analysis. The trials selected for analysis were those displaying the highest clubhead speed and showing no obvious differences in the ball velocity/clubhead speed ratio as measured by the launch monitor. The selected trials were also required to have minimal marker drop out during motion analysis data collection.

3.2 Data Collection and Analysis

In this study, a 10 camera opto-electronic MX-F20 Vicon-Peak Motion Analysis system (Oxford Metrics, Oxford, UK), operating at 500 Hz was used. The system’s accuracy was confirmed by determining the average of three trials for the distance between two markers of three known lengths of 300.6 (± 0.006 mm), 200.3 (± 0.003 mm), and 100.6 (± 0.005 mm).

3.2.1 Flexural Rigidity (EI) Testing

To determine whether stiffness of the two shafts used in this study was actually similar, the EI profiles of the two shafts were determined. This was done by using a slight variation on a previously published approach [16]. The above mentioned motion analysis system was used to measure deflection distances under a constant load applied to each shaft. In this protocol, the butt end of the shaft was clamped to a bench and a retro-reflective marker was positioned at the base of this clamp. A second retro-reflective marker was positioned at the same level on a stand-alone surface to provide a horizontal reference line, A third marker was then placed at the tip of the shaft. Deflection distance was considered as the vertical distance between the third marker and the line defining the horizontal. All deflection distances were measured with reference to the deflection distance under the shaft's own weight.

For the first trial of each EI profiling process, a weight of 15.5 N was hung from the tip of each shaft while the base of the grip was positioned level with the end of the bench. For all subsequent trials the same weight was hung from the shaft's tip and the cantilever distance was decreased by 5 cm. Three trials were recorded for each cantilever distance and an average deflection distance was calculated. Excellent reliability was found for deflection distance (Intraclass Correlation Coefficient = 0.999, relative Standard Error of Measurement = 2.9%), for both shafts. The following formula was used to determine the EI value at each cantilever length *n*,

$$EI_n = \frac{\frac{1}{3} F[l_n^3 - l_{n-1}^3]}{w(l_n) - \frac{1}{3} \frac{M_{n-1} l_{n-1}^3}{\overline{\overline{EI}}_{n-1}}}$$

where F was the force produced by the weight suspended from the tip of the shaft while l_n and $w(l_n)$ were the cantilever length and the deflection distance sampled at each point, respectively.

Further, M_n was the bending moment of each point sampled as determined by $F(l_n - l_{n-1})$ and EI_{n-1} was considered to be $Fl_{n-1}^3 / 3w(l_{n-1})$.

3.2.2 Swing Parameters and Related Launch Conditions

A real-time launch monitor (PureLaunch™, Zelocity, USA) positioned 4-5 m directly behind the hitting area and aimed down a target line, was used to measure two swing parameters (attack angle, clubhead speed at ball impact) and three launch conditions (ball velocity, launch angle and spin rate). Negative attack angle values (Figure 1) indicated that the clubhead was descending, in relation to the ground, at the point of ball impact [28]. The device's software predicted whether the ball would have landed within a 37 m wide fairway; shots landing outside were disregarded.

INSERT FIGURE 1 ABOUT HERE

To determine the validity of all five variables measured by the launch monitor in this study, except ball spin, eight high level amateur golfers (age = 23.5 years; handicap 2.2 ± 1.4) were recruited independently of the main study. Four variables were measured concurrently by the launch monitor and the above mentioned motion analysis system. A static calibration trial was obtained with three retro-reflective markers positioned in a triangular arrangement on top of the driver's clubhead, and four markers positioned at each corner of the clubface. A piece of retro-reflective tape was attached to the ball to act as a single marker. During the dynamic trials, the four clubface markers were removed and reconstructed as virtual markers. Clubhead speed at impact was calculated as change in displacement over time of the virtual central clubhead marker, as was ball velocity [29]. Attack angle was calculated at impact from the virtual central clubface marker referenced from a virtual global coordinate system [26]. Launch angle was calculated from the coordinates of the ball marker from the equation:

$$Launch\ angle\ \theta = tan\theta = (Zc - Zi)/(Xc - Xi)$$

where Xc and Xi were the current and initial positions of the ball in the horizontal direction respectively and Zc and Zi were the current and initial positions of the ball in the vertical direction [29]. Each participant hit six shots but three trials where maximal ball velocity was measured were chosen for analysis. All coordinate data were smoothed using a Woltring filter with a mean square error of 20 mm^2. All 3D modelling was undertaken using Vicon BodyBuilder V3.6.1. Pearson's product moment correlations were calculated for the four variables using STATA V9.1 (Stat Corp. Texas, USA). Results from this validation study revealed excellent correlations for the four variables (0.927-0.972) which indicated the launch monitor produces valid estimates for these variables.

Dynamic Kick Point Location and Amount of Shaft Bend

The same motion analysis system was used to determine the dynamic kick point location and the amount of shaft bend in the downswing. Eleven lightweight retro-reflective markers (1.4 cm in diameter) were positioned approximately in-line along each of the shafts, the first at the bottom of the grip and the rest equi-spaced down the shaft (7 cm apart). The most distal marker was positioned over the tip of the shaft. All coordinate data were smoothed as previously described.

To determine the dynamic kick point (quantified as the percentage of shaft length from the tip to the base of grip) with sub-marker precision, the shape of the shaft during the downswing was approximated. This involved using cubic spline interpolation from the top of the backswing – 0% (the frame in which the clubhead markers were shown to begin to move in the opposite direction, to commence the downswing) to the frame before ball impact – 100% (the frame prior to which the reflective tape on the ball was shown to move). The dynamic kick point was considered as the point on the shaft where the perpendicular distance, from a vector connecting the most proximal and distal markers on the club, was maximised. The amount of shaft bend occurring in the principal bending plane was also determined for each trial. Specifically, the Euclidian distance (the perpendicular distance as described above) was also quantified. The amount of shaft bend was determined at regular points in the downswing (0%, 20%, 40%, 60%, 80% and 100%).

The validity and reliability of the method for determining the dynamic kick point's location during the golf swing have been demonstrated [22]. When compared to measures taken by the club-fitter in a static sense, the motion-analysis method has shown excellent agreement (95% limits of agreement = -0.8 ± 3.1% of shaft length). High levels of between-trial reliability were recorded for dynamic kick point's location at maximum bending (Intra-class Correlation Coefficient = 0.936-0.957, relative Standard Error of Measurement = 0.4-1.1%).

3.3 Statistical Analysis

All data were initially screened and assumptions relating to parametric tests were met. To determine whether differences in the five swing parameters and related launch conditions existed between the drivers fitted with the shafts containing the high and low kick point, a repeated measures linear mixed model, using data from all trials, was used. The random factors were the swing parameters and related launch conditions, while the fixed factors were the two drivers with differing kick point location. Bonferroni corrections were applied for the coefficients of the mixed model with the alpha level set at 0.01.

To detect any significant associations between the five swing parameters and related launch conditions for each driver, Pearson's product moment correlations and the related 95% confidence intervals were calculated. The calculations were undertaken for both shafts. Repeated measures data should not be assumed as independent in a correlational analysis [30]. However, as the number of observations was the same for each participant, the means of the three observations were taken and the correlation values calculated on n=12 observations [31]. Correlation coefficient values between 0.2 and 0.4 were considered as weak associations, values between 0.4 and 0.7 were considered as moderate and values above 0.7 as strong [32].

Finally, to determine whether differences in the amount of shaft bend were evident between-drivers, a repeated measures linear mixed model was again used with all trials considered. The downswing (0-100% at 20% intervals) was entered as the repeated random factor and the two kick point drivers were entered as the fixed factor. While clubhead speed was initially included as a covariate for this analysis, it was not influential. Therefore, the repeated measures linear mixed model was re-run without clubhead speed. All statistical analyses were undertaken using STATA V9.1 (Stata Corp. Texas, USA).

4.0 Results:

The locations of the dynamic kick point for the drivers fitted with the high and low kick point shafts (determined statically) were 58.7 ± 3.2% and 62.1 ± 2.0% respectively. Therefore, the relative positioning of the low and high static kick points from dynamic evaluation was confirmed. Comparison of the EI profiles of the two shafts (Figure 2) revealed that the shaft containing the high kick point had greater stiffness when compared to the shaft containing the lower kick point at i) from the tip to 0.2 m of shaft length and ii) from 0.6 m from the tip to the butt. The EI values between 0.25 m – 0.55 m from the tip were very similar.

INSERT FIGURE 2 ABOUT HERE

The linear mixed model showed significant ($p<0.01$) differences, between the drivers containing differing kick point location, for three of the five swing parameters and related launch conditions (Table 2). Specifically, the driver fitted with the shaft containing the high kick point produced; higher values for ball spin rate, a more negative angle of attack, and a lower launch angle. The correlation analysis revealed a strong, positive association between clubhead speed and ball velocity for both drivers (Table 3). There was also a strong and negative relationship between launch angle and ball spin for the high kick point driver. Further, a moderate, positive association was found between the angle of attack and launch angle for the driver fitted with the high kick point shaft. Examination of the 95% confidence intervals for the four significant correlation values showed that none of these crossed zero.

INSERT TABLES 2 AND 3 ABOUT HERE

As revealed by ensemble averages of the three trials, the maximum amount of shaft bending for the driver fitted with the low kick point shaft occurred at 8.9 ± 4.0% into the downswing while the corresponding point for the high kick point shaft happened at 14.7 ± 3.5% (see Figure 3a). From the linear mixed model analysis, there was significantly more shaft bending at 0%, 20% and 40% of the downswing when compared to 60%, 80%, and 100% of the downswing (Figure 3b). While there was no significant difference ($p>0.05$) in the amount of shaft bending between the drivers with differing kick point locations, there was a significant difference ($p<0.05$) between the drivers at 80% and 100% of the downswing. Specifically, the driver containing the high kick point shaft showed more shaft bending when compared to the driver fitted with the low kick point shaft.

INSERT FIGURE 3A AND 3B ABOUT HERE

5.0 Discussion

While researchers have examined the effect of differences in shaft properties such as; mass, stiffness, length and swingweight on swing parameters and related launch conditions [8,18,19,26-27], we are unaware of any previous experimental research that has investigated the effect of kick point location on these variables. Consistent with previous anecdotal reports

[7,17,20,33], the driver fitted with the shaft containing the high kick point shaft displayed a more negative attack angle as well as a lower launch angle and greater spin rate. In stating these findings the difficulties in isolating the kick point variable should be highlighted. Firstly, the shafts used in this study had differing mass and this may have influenced the swingweights of the drivers. Therefore, as experienced by previous researchers who have investigated the effect of shaft mass and swingweight on swing parameters and related launch conditions [8,18-19], isolating the effect of a single club parameter is challenging. While isolating the effect of kick point location from shaft mass and swingweight in this study was not possible, it is worth noting that swingweight has previously been shown to have no effect on swing parameters and related launch conditions such as; clubhead speed [8], ball velocity, launch angle and ball spin [9,18]. In this study there was no effect of kick point location on clubhead speed. Although other simulation studies had predicted an increased clubhead speed for lighter shafts, the experimental evidence suggests elite golfers do not respond to changes in shaft mass in a mechanically predictable way [8,18,34].

While we tested two “stiff” shafts in this study, the actual stiffness along the length of the shaft was quantified using EI profiles [16]. From this analysis, it was found that the tip and butt sections of the two shafts differed slightly with respect to their EI values. This is an important consideration as there is anecdotal evidence that tip stiffness may influence launch angle [35]. The current study found that the driver fitted with the shaft containing the low kick point had a lower stiffness at the tip of the shaft and this may have contributed to the higher launch angle recorded with this driver. Moreover, impact location has been shown to influence launch conditions such as the launch angle [36-38] and this should be considered in future research.

Unsurprisingly, the correlation analyses between the swing parameters and related launch conditions revealed a strong and positive relationship between clubhead speed and ball velocity for both drivers [19]. Of more interest however, was the examination of relationships between the three variables that differed between the drivers. Preliminary evidence from others [12,28] has led to the belief that a more negative angle of attack may result in an increased spin rate on the ball and a lower launch angle. Indeed there was moderate and positive association between attack angle and launch angle for the driver fitted with the shaft containing the high kick point which indicated that participants who hit down on the ball more had lower launch angles. However, this significant association was not evident for the driver containing the low kick point shaft. The strong, negative relationship between launch angle and spin rate for the driver fitted with the shaft containing the high kick point. There was also a similar negative moderate, but non-significant correlation for the driver containing the low kick point. Increased spin imparted on the ball was associated with lower launch angles and this finding supports previous research [28,39] where elite golfers who aim to maximise clubhead speed off the tee lowered their launch angles and imparted greater spin on the ball when attempting to maximise driving distance.

As mentioned above, the driver fitted with the shaft containing the high kick point displayed a more negative angle of attack. This difference is probably due to the lag created by the significant between-driver difference in kick point location, which is thought to affect the presentation of the clubface to the ball at impact [12,28]. As clubhead presentation can be determined by bending of the shaft [9,22], an examination of shaft bending during the downswing was also undertaken in this study. As shown in Figure 3a and 3b there was a general trend for the amount of shaft bending to decrease throughout the downswing. Whilst no significant between-driver differences were found in the amount of shaft bending early in the downswing, differences were seen at 80% of the downswing and one frame before impact (100%). The full story of lagging of the shaft cannot be elucidated by this study as only bending in the principal plane was measured. Hence, the amount of lag/lead and toe-up/toe-down could not be quantified. It is known from experimental [11] and simulation [27] studies that the greatest amount of shaft bending occurs at the top of the backswing and this takes the form of predominantly toe-up bending. However, at around 60% of the downswing, lagging of the shaft increases more rapidly while toe-up bending begins to transition into toe-down bending. Therefore, it is possible that the differences found at 80% of the downswing in the current study are due to shaft lag. However, this needs to be confirmed in future work. It is also worth noting that while the changes in the angle of attack may have been due to altered shaft dynamics, the swing path, which was not measured in the study, and the difference in the EI profiles of the two shafts, cannot be discounted [27].

Some limitations of the study should be acknowledged. Firstly, as stated above the kick point variable was not completely isolated in this study as there were differences between-driver for shaft mass, swing weighting and EI profiles. Secondly, this investigation only examined a small cohort of participants which included a mixture of high-level amateur and elite golfers who swung drivers fitted with "stiff" shafts. Thirdly, swing parameters and related launch conditions, such as clubhead orientation, and impact location, were not examined in this study. The exclusion of impact location in this study meant that clubhead speed was the most suitable outcome available for measuring ball distance [5,40,41]. Future investigations may wish to assess ball velocity instead if impact location is considered. Fourthly, as the principal bending plane of the shaft was examined in this study, it is unclear as to which component of bending (toe up / down, and lead / lag) was occurring and if this was known, a better understanding of the between-driver differences could be achieved. The use of strain gauges attached to the shafts would clearly identify not only the dominant bending plane, but also the interaction between the two planes, throughout the downswing. Finally, this study was conducted indoors and involved a short familiarisation period, therefore, participants did not have long to be able to visually perceive shot outcome and consequently adapt to the different clubs provided. It should also be mentioned that there may be an effect of player-ability with respect to this consideration.

In conclusion, this study revealed that a driver fitted with a shaft containing a high kick point displayed; a more negative attack angle, a lower launch angle and a greater rate of ball spin when compared to a driver fitted with a low kick point shaft. It is possible that the difference found in the attack angle may have resulted, in part, from the differences found for launch angle and ball spin. The correlation analysis between these variables resulted in some support for this hypothesis but further investigation of these relationships may be worthwhile. It is possible the attack angle differed between the drivers, due to the greater amount of shaft bending found in the late downswing (80% and just before impact) for the driver containing the higher kick point. The amount of shaft bending may have also been influenced by the differing EI profiles. Measurement of shaft lag in future studies is also recommended. The findings of this study may benefit golf teaching professionals, club-fitters, and biomechanists seeking to optimise a golfer's swing parameters and related launch conditions.

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Figure and Table Captions:

Figure 1. Defining positive (left) and negative (right) attack angle (club-head) and effect on launch angle (ball).

Figure 2. Flexural rigidity (EI) profiles for the two shafts used in this study. Higher EI values indicate higher stiffness.

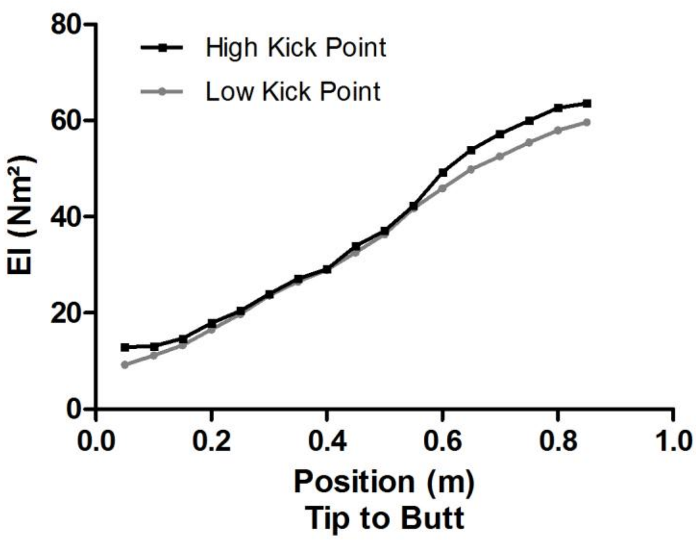

Figure 3. Amount of shaft bend from Top of Backswing (0%) to Ball Impact (100%) for the drivers fitted with the high and low kick point shafts. Data are presented as a) an ensemble average of the continuous data and b) at a series of discrete data points. From the main effects

analysis, the conditions bound by the box (60%, 80% and 100%) were all significantly different (* p<0.05) to 0%, 20%, and 40%. From the simple effects analysis there were between-driver differences (** p<0.05) evident at 80% and 100% of the downswing.

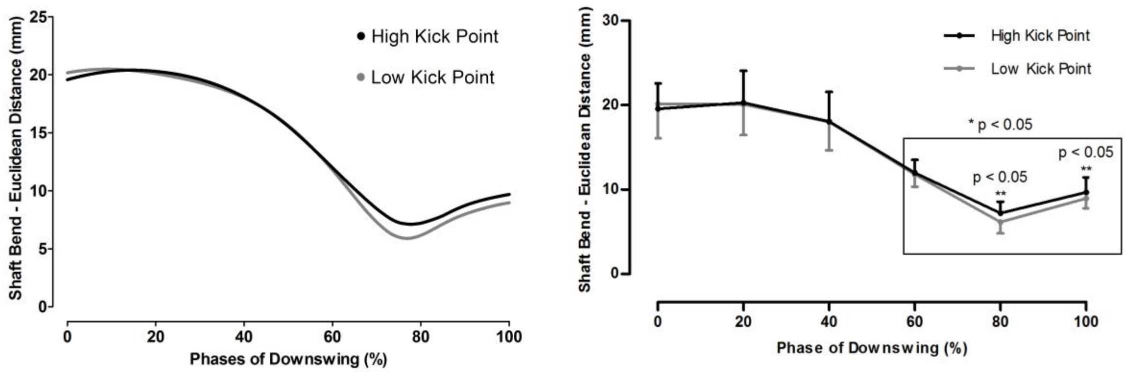

Table 1. Properties of the drivers fitted with shafts containing the high and low kick points. A mean ± SD value is provided for the static kick point value only.

	High Kick Point	**Low Kick Point**
Static Kick Point (% of length from club tip)	58.4 ± 1.5	55.3 ± 1.5
Shaft Mass (kg)	0.078	0.056
Shaft Stiffness (cpm)	238.0	241.0
Torsional Stiffness (°)	4.0	3.0
Centre of Mass (m from butt)	0.858	0.834
Shaft-Weighting (category)	D3	D1
Moment of Inertia about CoM ($kg.m^2$)	0.039	0.036
Club Length - grip, shaft and club-head (m)	1.19	1.19
Club-head mass (kg)	0.200	0.200
Club-head face angle (°)	10.5	10.5

Table 2. Mean ± SD swing parameters and related launch conditions for drivers fitted with shafts containing high and low kick points (n=36 for each shaft).

	High Kick Point Mean ± SD	**Low Kick Point Mean ± SD**
Clubhead Speed (m/s)	48 ± 2	48 ± 2
Ball Velocity (m/s)	67 ± 2	66 ± 3
Launch Angle (°)*	8 ± 2	10 ± 2
Attack Angle (°)*	-3 ± 1	-1 ± 2
Spin Rate (rpm)*	4168 ± 495	3614 ± 531

* - indicates a significant difference ($p \leq 0.01$) between-shaft.

Table 3. Correlation coefficient values between the swing parameters and related launch conditions (n=12). These values were calculated separately for the drivers fitted with the shafts containing the high (top figure) and low (bottom figure) kick points. The 95% confidence intervals are also reported in brackets.

	Clubhead Speed	**Ball Velocity**	**Launch Angle**	**Attack Angle**	**Spin Rate**
Clubhead Speed					
Ball Velocity	0.735 (0.54 : 0.86)** 0.701 (0.48 : 0.84)*				
Launch Angle	0.243 (-0.09 : 0.53) 0.409 (0.09 : 0.65)	0.428 (0.12 : 0.66) 0.042 (-0.29 : 0.37)			
Attack Angle	0.047 (-0.29 : 0.37) 0.184 (-0.15 : 0.48)	0.331 (0.00 : 0.59) 0.242 (-0.09 : 0.53)	0.576 (0.31 : 0.76)* 0.305 (-0.03 : 0.58)		
Spin Rate	-0.327 (-0.59 : 0.00) -0.410 (-0.65 : -0.09)	-0.531 (-0.73 : -0.25) 0.094 (-0.24 : 0.41)	-0.905 (-0.95 : -0.82)** -0.543 (-0.74 : -0.26)	-0.384 (-0.63 : -0.06) -0.475 (-0.70 : -0.17)	

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)