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THE EFFECTS OF THE DEFLECTION POINT AND SHAFT MASS ON SWING AND LAUNCH PARAMETERS IN THE GOLF SWING

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This study determined whether a higher dynamic deflection point (DDP) was evident when using a driver fitted with a stiff shaft of greater mass and whether between-shaft differences were evident in swing and launch parameters. Twelve elite male golfers had three shots analysed for each of two drivers fitted with “stiff” shafts of different mass (56 g and 78 g). Six swing and launch parameters were measured by a real-time launch monitor and the (DDP) was measured using a motion analysis system. Between-shaft differences were evident for the DDP at maximum, but not at ball impact. Between-shaft differences in swing and launch parameters for the heavier shaft resulted in; lower launch angles ($p < 0.001$), increased spin rates ($p < 0.001$) and steeper attack angles ($p < 0.001$). The findings show the importance of DDP and optimising swing and launch parameters.

KEY WORDS: golf, swing, shaft, launch, deflection.

INTRODUCTION: All methods to increase hitting distance off the tee in golf should be considered, including club characteristics. Important properties of the golf club's shaft include; stiffness, damping, torsional stiffness, mass, and maximum deflection point (or kick point) (Wallace & Hubbell, 2001; Cheong, Kang, & Jeong, 2006). Whilst previous authors suggest that golfers attempt to use bending of the shaft to maximise clubhead speed (Mather, Smith, Jowett, Gibson, & Moynihan, 2000; McGinnis & Nesbit, 2010; Betzler et al., 2011), the experimental evidence is less convincing (Wallace & Hubbell, 2001).

The maximum deflection point of a golf club is measured under static conditions and is typically considered as the furthest point from a line joining the two ends of a loaded shaft (Jackson, 2001). The deflection point of clubs used by high level players occurs between 44–60% of shaft length when expressed as a distance from the club's tip (Mather et al., 2000; Cheong et al., 2006). It has been postulated that heavier shafts provide a higher deflection point and result in lower ball launch angles (Mather et al., 2000; Summitt, 2000; Jackson, 2001; Cheong et al., 2006). However, little objective evidence of the dynamic behaviour of the shaft exists to support these claims. Whether other launch (ball) and swing (club) parameters, such as attack angle of the clubface into the ball vary with changes to shaft mass has not been reported by other researchers.

Swing and launch parameters influence carry distance. For example, a positive attack angle (where the club ascends in relation to the ground at ball impact), higher launch angle and lower spin rate are all believed to result in increased carry distance. Specifically, excessive ball spin created from a negative attack angle is believed to reduce carry distance (King & DeNunzio, 2008; Tuxen, 2008), however, research into how the shaft influences this is needed.

This study was conducted to determine whether a higher dynamic deflection point (DDP) was evident when using a driver fitted with a shaft of greater mass, and whether between-shaft differences were evident in selected swing and launch parameters.

METHODS: Twelve right-handed elite male golfers (mean \pm SD; age 24.7 \pm 6.0 y, handicap 1.2 \pm 1.8 score) were recruited based on criteria of having; a registered golfing handicap \leq 5 and being aged between 18-35 years. All participants were informed of the research

procedures prior to testing and all provided informed consent. Ethical clearance to conduct the study was provided by the Institutional Human Research Ethics Committee.

In this study each participant used two drivers. Each driver had the same grip (length=0.27 m) and driver head (mass=200 g, face angle=10 °), however, two interchangeable Graphite Design™ YS5 (56 g) and YS7 (78 g) “stiff” shafts (1.13 m long, inclusive of grip) were used. These shafts were used as they are used by elite-level players.

Prior to this study, an approach to determine the DDP of the shaft was developed. This involved positioning 11 lightweight retro-reflective markers (1.4 cm diameter) along the shaft of the golf club. One of these markers was placed at the bottom of the grip (P1), while the remaining 10 markers (P2-P11) were equi-spaced down the shaft (7 cm apart), so as the last marker (P11) was positioned over the tip of the shaft. Under static conditions, when the club was bent, the deflection 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 shape of the shaft was approximated using cubic spline interpolation. This process generated 101 points per frame so that the deflection point could be determined with sub-marker precision.

This method was validated by comparing estimates of the static deflection point (SDP) determined by a professional club-fitter, to those made by an algorithm that used coordinates of the 11 markers captured by a 10-camera, MX-F20 Vicon-Peak Motion Analysis system (Oxford Metrics, Oxford, UK) operating at 500 Hz. To determine the SDP, the club fitter fixed each club in a vice (10 drivers fitted with shafts of varying stiffness and mass were used), and a 2.3 kg load was suspended from the distal end of the shaft (Jackson, 2001). Once the golf club/load system was stabilised, the SDP was visually determined with the aid of a shaft kick-point board (Surrey Golf, Australia). From the Bland-Altman plot and limits of agreement statistics (Figure 1), there was minimal systematic bias.

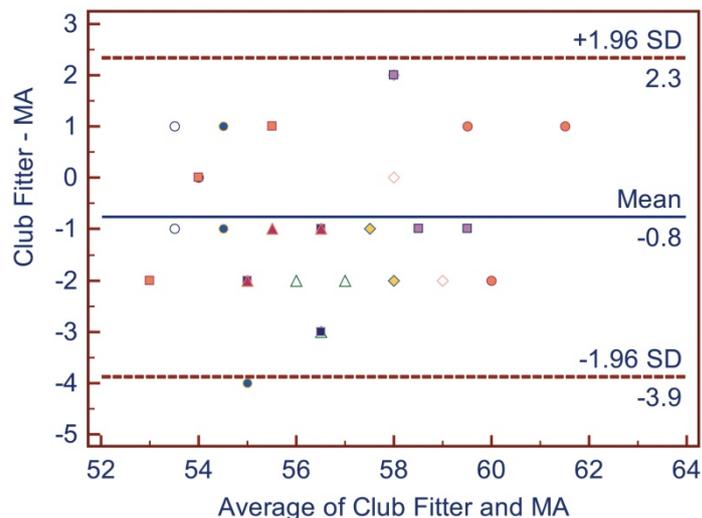


Figure 1: Bland-Altman plot with multiple measurements per shaft showing the 95% limits of agreement between the professional club fitter and the Motion Analysis (MA) method. Data were measured in percentage of shaft length.

During golf swing testing, each participant hit a total of 12 shots (six shots per club). To eliminate potential bias, participants were blinded to the mass of the shaft that was fitted to the drivers they were using. Shots were hit from an artificial turf surface into a net positioned 5 m in front of the player. Participants were instructed to hit the golf ball straight with maximum velocity. A real-time launch monitor (PureLaunch™, Zelocity, USA) was positioned 4-5 m directly behind the hitting area to measure selected swing and launch parameters and was also used to ensure the ball was hit within a standard 37 m wide fairway (USGA).

Three of six shots hit using each shaft were analysed. The selected trials were those displaying maximal clubhead speed and minimal marker drop out. All coordinate data were

smoothed, using a Woltring filter with a mean square error of 20 mm². The resulting coordinate data were then exported as text files and were subsequently analysed using the above mentioned algorithm implemented with Microsoft Excel.

For each shot hit, the DDP at point of maximum bend and at ball impact was calculated. Maximum bend was identified as a time period relative to the top of the backswing. Top of the backswing was defined as the frame where the grip marker (P1) changed direction to initiate the downswing. Ball impact was considered as the frame where the golf ball was shown to commence movement as determined by a retro-reflective marker positioned on the ball. Six swing and launch parameters were collected from the launch monitor at ball impact, they being; clubhead speed, ball velocity, launch angle (of ball), spin rate, attack angle (of club-face), and predicted carry distance. Negative angle of attack values indicated that the clubhead was descending, in relation to the ground, at the point of ball impact (Tuxen, 2008). Between-trial reliability of DDP locations at maximum and ball impact was determined using intra-class correlation coefficients (ICC (3,3)) and absolute Standard Error of Measurement (SEM). Independent t-tests were then conducted to determine whether the DDP locations differed between-club (56 g and 78 g shafts). Paired t-tests were used to determine whether parameters measured by the launch monitor differed between-shaft. All standard assumptions for parametric tests were met. Bonferroni adjustments were made for each type of t-test therefore, alpha levels were set at 0.025 for DDP variables, and 0.008 for swing and launch parameters. To determine whether relationships existed between selected swing and launch parameters and predicted carry distance, Pearson's Correlation Coefficients were conducted for swing and launch parameters of each shaft. For these analyses, $p \leq 0.05$ denoted significance. All analyses were performed using SPSS V19.0 for Windows (SPSS Inc, Seattle, WA, USA).

RESULTS AND DISCUSSION: Good to excellent levels of reliability were found for firstly, the location of the DDP at maximum (ICC=0.936-0.957, SEM=0.4-1.1%) and ball impact (ICC=0.932-0.951, SEM=0.8-1.2%) and secondly, the variables generated from the launch monitor that are reported in Table 1. Therefore, the data from three trials were averaged to provide a single, representative data point for each participant. The DDP at maximum bend occurred at 0.082 s (± 0.038 s) after the top of the backswing for both clubs. A significant difference ($p=0.019$) was found for the DDP at maximum between the driver fitted with the 56 g shaft ($58.7 \pm 4.2\%$ from the club tip) and the club fitted with the 78 g shaft ($62.1 \pm 2.0\%$). No between-shaft difference ($p=0.190$) was found for DDP at ball impact (56 g - $51.1 \pm 4.7\%$, 78 g - $54.3 \pm 3.8\%$). Between-shaft differences were evident for launch angle, spin rate and attack angle (Table 1). For the heavy shaft, spin rate was negatively ($r=-0.790$, $p<0.05$), and attack angle ($r=0.622$, $p<0.05$) positively associated with predicted carry distance. The findings of a lower DDP and greater launch angle for the lighter shaft were consistent with previous anecdotal reports (Mather et al., 2000; Jackson, 2001; Cheong et al., 2006). Compared to the heavier shaft, the lighter shaft experiences a lower rotational inertia, due to a smaller moment arm between the clubhead and lower DDP. This reduces the lag of the clubhead in the downswing and this may help produce higher launch angles and a less negative attack angle at ball impact. (Mather et al., 2000; Summitt, 2000; Jackson, 2001; Cheong et al., 2006; King & DeNunzio, 2008; Tuxen, 2008). The higher DDP for the heavier shaft experienced a greater rotational inertia, which increased the lag of the clubhead and produced a lower launch angle and a more negative attack angle. The heavier shaft displayed an increased spin rate at ball impact. Due to the absence of between-shaft differences in clubhead speed and ball velocity, predicted carry distance was probably influenced by the significant between-shaft differences in launch parameters.

It has previously been stated that elite golfers who use heavier shafts with a higher SDP, will induce faster clubhead speeds to increase predicted carry distance (Mather et al., 2000; Tuxen, 2008). However, with no between-shaft difference in clubhead speed and ball velocity, and a higher spin rate seen for the heavier shaft, this may have lead to similar between-shaft values of predicted carry distance. A potential limitation of the study was that aerodynamic performance of the clubs may have been influenced by the markers being

placed on the club however, as markers were placed on both clubs, the effect of this potential problems was effectively controlled for.

Table 1: Mean (SD) and reliability (ICC & SEM) data from the real-time launch monitor for drivers fitted with 56 g and 78 g “stiff” shafts. Indices of reliability are also reported.

| | 56 g shaft Mean (SD) | ICC | SEM | 78 g shaft Mean (SD) | ICC | SEM |
|---------------------------------|-------------------------|-------|-----|-------------------------|-------|-----|
| Clubhead Speed (m/s) | 48 (2) | 0.908 | 1 | 48 (2) | 0.940 | 1 |
| Ball Velocity (m/s) | 67 (2) | 0.867 | 1 | 67 (2) | 0.905 | 1 |
| Launch Angle (°)* | 11 (3) | 0.872 | 1 | 8 (2) | 0.912 | 1 |
| Attack Angle (°)* | -2 (3) | 0.841 | 1 | -3 (1) | 0.856 | 1 |
| Spin Rate (rpm)* | 3578 (407) | 0.802 | 181 | 4166 (438) | 0.797 | 197 |
| Predicted Carry Distance (m) | 215 (7) | 0.786 | 3 | 212 (15) | 0.902 | 4 |

* - indicates a significant difference ($p \leq 0.008$) between-shaft.

CONCLUSIONS: A between-shaft difference was evident for DDP location at maximum, which is consistent with findings from previous authors stating that heavier shafts have a higher deflection point. While no between-shaft differences were evident for clubhead speed or ball velocity, elite golfers using the driver fitted with the 78 g shaft produced lower launch angles, an increased spin rate and a more negative attack angle when compared to the 56 g shaft. However, no difference was seen for predicted carry distance which may have been due to between-shaft differences in spin rate and attack angle. The findings of this study are of benefit to golf teaching professionals, club-fitters, and biomechanists, whose aim it is to understand how DDP of differently weighted shafts differs during the downswing, and what affect this has when attempting to optimise launch parameters.

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