THREE DIMENSIONAL ANALYSES OF CLUB MOVEMENT AND CLUBHEAD ORIENTATION AT IMPACT DURING THE GOLF SWING

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INTRODUCTION

The direction of a golf shot is determined in part by the direction of clubhead movement and orientation of the clubface during impact. As a result of the collision of the club with the ball, the clubface orientation changes during impact, and this is likely to have an effect on the speed and flight path of the ball. The purpose of this study was to investigate how club movement and clubhead orientation at ball impact varies within and between groups of golfers of different skill levels.

METHODS

Kinematic data was obtained using a Motion Analysis (MAS) automated three-dimensional video analysis system and three high-speed cameras. During the swing the system tracked three spherical reflective markers attached to the clubs. In order to locate the clubface relative to the club markers, four reflective markers were place on the clubface and filmed during a special calibration procedure. A transformation matrix allowed 3-D clubface marker coordinates to be predicted once the 3-D coordinates of the club markers were known.

Three angles were calculated from the clubface markers and used to describe the orientation of the clubface at impact - Loft, Open/Closed, and Tilt angles. Two angles were used to identify the direction of movement of the clubface at impact, one measuring the up/down (vertical) direction and the other the inside-out or push/pull (horizontal) direction. The location of the ball impact on the clubface was measured relative to the approximate center of each club. The clubface was found to show large changes in loft and open/closed angles as a result of impact during the 20-25 ms period after impact. A method was developed to calculate a neutral axis based on impact location and the associated changes in loft and open/closed angles. Analysis of variance was used to identify significant differences between skill levels.

RESULTS AND DISCUSSION

The low handicap group's average speed with the driver of 99.2 mph was significantly greater than the medium group's 86.9 mph and the low group's 76.6 mph, and the correlation between handicap and impact speed was -0.70 (See Table 1 for driver data). The high handicap group had a significantly more open clubface at impact using the driver compared to the low and the medium groups, and the high handicap group was also significantly more open with the 5-iron (low: 4.0°; Med: 2.4°; high: 8.1°). For the driver and the 5-iron, the low and medium groups had on average a slight inside-out (push) swing, and these values were significantly different from the average outside-in (pull) swing of the high handicap group. The combination of a pull direction of impact and an open clubface would make the high handicappers more likely to slice the ball with both clubs compared to the other two groups.

A significant difference between handicap groups was found in the vertical position of impact of the ball relative to the club center with the 5-iron, with the high handicap group (-0.07 cm) significantly lower on the clubface at impact compared to the medium (0.47 cm) or low (0.69 cm) groups. This vertical impact position for the high handicap group showed that on average they did not penetrate into the surface below the ball when hitting the iron, while the low handicap group had the bottom edge of the club penetrating 1.31 cm below the lowest point on the ball. The ball impact location with the 5-iron for the high handicap group would increase the risk of "topping" the ball.

Significant differences were found throughout the data set where the high handicap group showed the greatest variability between swings for various measures characterizing impact conditions, and the low handicap group typically had the least variability, as would be expected.

CONCLUSIONS

Variations in biomechanical measures of club impact conditions showed considerable variability between handicap levels of golfers, with low handicappers showing faster swings, impact conditions that should lead to a straighter shot, and with less variability between swings. This type of information is relevant to design of equipment used in golf, allowing for clubs or balls to be "tuned" to the skill level of the golfer. It also identifies characteristics that might help focus instruction for golfers of different skill levels.

REFERENCES

1. Williams, KR et al. Changes In Golf Clubface Orientation Following Impact With The Ball. *J. Sports Engineering* , **5**(2): 65-80, 2002

Handicap Group	Handicap	Clubhead Speed	Loft Angle Up(+)/Down	Open/Closed Angle Open(+)/Closed	Velocity Angle Push(+)/Pull	Average SD of Swing Plane Angle
	(strokes)	($m \cdot s^{-1}$)	(°)	(°)	(°)	(°)
Low	1.5 ± 1.5	44.3 ± 2.6	16.9 ± 4.3	3.8 ± 4.0	1.6 ± 3.8	1.5
Medium	13.8 ± 2.9	38.8 ± 5.3	15.7 ± 4.4	3.6 ± 3.4	0.8 ± 4.2	2.3
High	28.7 ± 4.9	34.2 ± 3.5	18.2 ± 3.9	11.0 ± 4.9	-1.1 ± 3.7	3.2

Table 1: Data across handicap groups for measures obtained at ball impact using the driver.