A 3-D DETERMINATION AND ANALYSIS OF THE SWING PLANE IN GOLF

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INTRODUCTION: The direction and ball carry distance of a golf shot are determined by the trajectory of the clubhead near the impact and the impact conditions such as the clubhead speed, club face angle and orientation at impact. Swing plane, one of the most frequently used terms in golf coaching lately, is also one of the most controversial and misleading concepts: single-plane, multi-plane, one-plane, two-plane, on-plane, etc. The purpose of this study was twofold: (a) to develop a method to determine the true swing plane based on the clubhead motion (trajectory), and (b) to obtain a biomechanical profile of the swing planes of professional golfers through the swing plane analysis.

METHODS: Ten male PGA professionals (Handicap 1 or less) participated in this study. The swing plane was defined as the plane closest to the trajectory of the club head. Flatness (RMS deviation of the clubhead trajectory from the swing plane), inclination, and direction angle of the swing plane were computed from the clubhead trajectory. The swing plane was assessed in three different phases of the swing that contain the ball impact: backswing top to horizontal club position after impact (TH), vertical club position to horizontal club position after impact (VH), and horizontal club position to horizontal club position after impact (HH). Participants used 3 different clubs (driver, 5-iron, and pitching wedge). The positions of the clubhead and select body landmarks were obtained through a 3-D video motion analysis (60 Hz) with 8 cameras. The position data were interpolated to 200 Hz for further analysis. Two-way ANOVAs (phase x club) were used in the statistical analyses ($p < .05$).

RESULTS: The flatness data for different phase-club conditions and the swing plane profiles for the HH-phase conditions are presented in Table 1.

Table 1 Swing Plane Profiles

	Flatness (cm)			Inclination (deg)	Direction Angle (deg)
	HH	VH	TH	HH	HH
Driver	0.9 ± 0.4	6.4 ± 1.2 [§]	6.4 ± 1.9 [§]	49.8 ± 2.9	-1.4 ± 5.6
5-iron	0.8 ± 0.5	3.2 ± 0.9 [§£]	4.2 ± 1.1 [§£]	59.1 ± 2.2 [£]	0.3 ± 3.5
PW	0.5 ± 0.3 [£]	2.4 ± 0.6 [§£¥]	3.7 ± 0.9 [§Ç£]	63.1 ± 1.4 [£]	-1.2 ± 2.9

[§] Significantly different from the matching HH condition ($p < .05$); [Ç] Significantly different from the matching VH condition ($p < .05$); [£] Significantly different from the matching driver condition ($p < .05$); [¥] Significantly different from the matching 5-iron condition ($p < .05$).

DISCUSSION: The flatness values of the VH and TH conditions were significantly larger (less flatter) than those of the HH phase (< 1 cm) in all clubs, suggesting that (a) a single plane existed only in the HH phase, and (b) the swing plane kept changing during the initial phase of the downswing (backswing top to the horizontal position of the club). Shorter clubs showed a tendency of flatter swing planes than the driver plane. The inclination values for 5-iron and PW were significantly larger than that of the driver for the HH swing plane, meaning that the longer the club is the flatter the swing plane becomes. There were no significant differences in the direction angle among the clubs, indicating that club selection has little influence on the angle of impact. Potential applications of the swing plane obtained from the clubhead motion were further explored in this study.