GOLFER-CLUB INTERACTION DURING SWING AND ITS INFLUENCES ON MOTOR CONTROL STRATEGIES EMPLOYED BY ADVANCED GOLFERS

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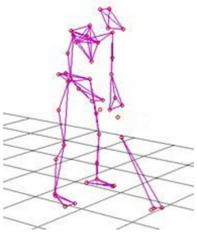
Many studies have been done to understand the kinematics of golf swing techniques. However a holistic picture of an efficient swing remains incomplete due to constraints of data collection techniques. Force measurement, on the other hand, has been used successfully in the past to examine weight shift patterns of a golfer during the swing. Yet, the shift involves the dynamic effect of a club. The degree of the club contribution to the weight shift patterns, however, is still unknown. This study attempted to explore this issue. A synchronized data collection of 3D motion capture (12 high-speed cameras [120 Hz], VICON v8i) and ground reaction force (2 KISTLER platforms) was utilized. Nine advanced golfers were measured. The results showed that 1) the dynamic influence of the club was closely related to one's motor control pattern, especially wrist and elbow control during swing, i.e. they determined the degree of separation between centre of ground reaction force (CGRF) and centre of gravity (COG); 2) a Driver has more influence on a golfer's weight transfer (larger range of variation and more separation) than an Iron; 3) the club head speed is highly related to the coordination between shoulder and hip angle (a factor determining the quality of trunk rotation); and 4) the ball release velocity is influenced by wrist flexion at ball contact which could be identified by the separation between CGRF and COG.

KEY WORDS: 3D analysis, weight transfer, coordination, release speed.

INTRODUCTION: Golf swings are complicated movements that require coordination of all major body segments. Although studies on whole body coordination have been done in the past, the number of 3D motion analysis studies is relatively small. Previous studies dealing with descriptions and simulations of golf swings (Trevino, 1992; Pickering & Vickers 1999; Sprigings & Neal 2000; Egret, et al, 2003) have either focused on specific body segments (e.g. arms, feet) or had limitations on kinematic data collection (results were not reliably three dimensional and whole body). Hence, there is a need to gain knowledge of full body kinematics of the golf swing. Force measurement, on the other hand, has been successfully used in the past to examine weight shift patterns of beginner and/or advanced golfer during the swing (Richards, et al, 1985; Koslow, 1994). The combined measurement of both is still rare and only one with limited 3D motion analysis was found (Spence, Caldwell & Hudson, 1996). However, it should be mentioned that the force platform data captured weight transfer patterns of the golfer with the golf club. To our best knowledge, there is no study dealing with the dynamic influence of the club on golfers' weight transfer during swing. Studies on body-equipment interactions will certainly supply valuable information on training (motor learning) and equipment optimization/individualization. Therefore the aims of this study are: 1) to characterize advanced golfers using 3D capture, 2) to quantify the golfer-club interaction and determine the influences of the interaction on motor control strategies employed by different golfers and 3) to explore ways/parameters that can be used to quantify the interaction and to evaluate the swing quality.

METHODS: In order to quantitatively determine the whole body kinematic characteristics during a swing, 3D motion capture was used. Specifically, a twelve-camera VICON v8i motion capture system (Oxford Metrics Ltd., Oxford, England) will gather positional data from the subjects at 120 f/s. Each of the subjects wore a black garment made of stretchable material, which covered the upper and lower body. Affixed to the garment were 42 reflective markers, each with a diameter of 9mm. They were placed on the anterior superior iliac crest, posterior superior iliac crest, lateral condyle of the tibia, lateral malleolous of the fibula, calcaneal tuberosity, tuberosity of the fifth metatarsal and the head of hallicus, as well as on the upper and lower leg. The upper body will have markers placed on the acromion process, lateral epicondyle of the humerous, styloid process of the ulna and radius, third metacarpophalangeal joint, as well as the upper and lower arm, sternal notch, xiphoid process, C7, T10 and left and right back. Four markers will also be placed on the head. The markers reflect infrared light to the cameras positioned around the subject as shown in Figure 1a. From these 42 markers, a full body biomechanical model (15 segments, Figure 1b) was built to determine the transfer of centre of gravity (COG), joints angles and their ranges of motion (ROMs) during a swing. The quantitative determination of COG was done with the help of individual anthropometrical data obtained through subject's body weight and body height (Shan & Bohn, 2003). In addition, markers were attached on the shaft (one) and the head (two) of the club to establish club orientation and club head speed. As well, reflective tape was glued to a standard golf ball to determine ball release velocity.


(a)

(b)

Figure 1: (a) Exemplars raw data (b) Model after performing model calculations

Two KISTLER force platforms were used to capture the weight transfer during a golf swing under each foot. It should be noticed that the captured data – known as CGRF – reveals the transfer patterns of the golfer-club system (a joint effect). By comparing CGRF to COG (obtained through 3D motion capture and biomechanical modeling), the effects of club on swing techniques can be quantified.

Empirical evidence has proved that it is an effective way to utilize trunk rotation in order to increase club swing speed. Since the trunk rotation decreases the control accuracy, the hip-shoulder coordination should be a factor for evaluating swing quality. An analysis of timely coordination of these two joints was conducted for searching the relationship between trunk rotation and ball release speed.

Nine advanced golfers were recruited. They had in average 10 years of golf experience. All participants completed an informed consent form for human subjects' tests. Subjects were allowed to perform a sufficient number of warm up swings to get used to the test environment. After warm-up they performed 3 good golf swings with a driver and 3 with a #7 iron. During each swing, the kinematic (3D motion) and kinetic (GRF) data were captured simultaneously. No restrictions were given to the subject before and during trials. Basic statistics were applied to determine the central tendency, standard variation and some correlations of the group's measurements.

RESULTS AND DISCUSSION: The variation within the group is obvious. A summary of selected parameters is shown in Table 1. Since there is no data in other levels (novice or professional) available currently, subjects' comparison was used to show body-club interaction and how it relates to swing quality/technique evaluation.

Table 1: Group performance of selected parameters and their standard deviation

	Max. Separation (mm)		**Down-swing time (s)**	**Mean Trunk Rotation (°/s)**	**Speed (m/s)**	
	M-L	**A-P**			**Club Head**	**Ball**
Driver	35 ±17	28 ± 9	0.254 ± .006	149 ± 32	35.7 ± 2.8	56.5 ± 8.2
#7 Iron	7 ± 11	20 ± 8	0.242 ± .008	151 ± 29	30.2 ± 1.8	48.1 ± 5.3

Figure 2 shows two different clubs (Driver & #7 Iron) and control patterns among the tested advanced golfers. Generally speaking, both CGRF and COG transferred more in the medial-lateral (M-L) direction than in the anterior-posterior (A-P) for both Driver and #7 Iron clubs; a Driver had more influence on the golfer's weight transfer (dynamic balancing) than the Iron in both directions and the left foot shared more weight than the right during a swing.

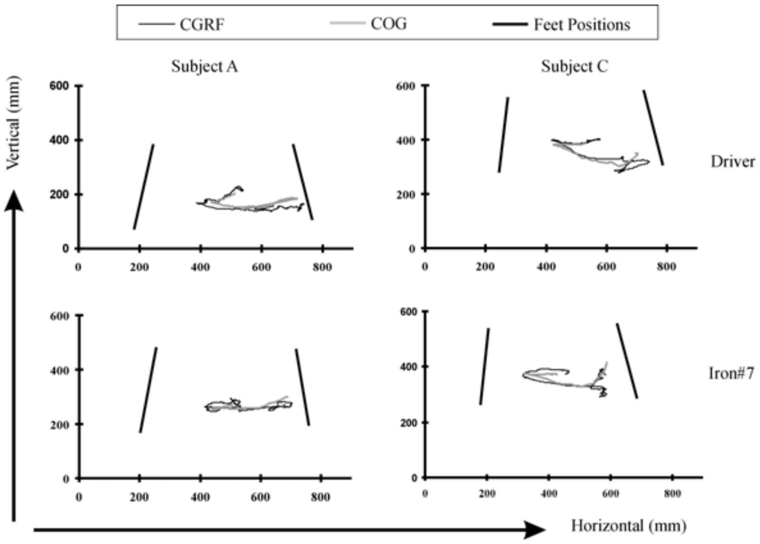


Figure 2: Excursions of CGRF and COG during swings using Driver and #7 Iron.

However, the results revealed that the dynamic interaction between club and golfer (or the separation of CGRF and COG) is highly related to motor control strategies employed by individuals. The 3D motion analysis showed that Subject A employed a control strategy that used more opened elbow and stabilized wrist in compared with Subject C when the Driver was used. Such a strategy simplified the motor control during the swing. However, it increased the max. separation (Subject A: 53.9 mm & Subject C: 6 mm) in M-L direction. Such a separation was highly correlated (r=0.79) to an angle determined by shoulder, wrist and club head (βs-w-ch). This parameter reflects how close the club was to the body during down-swing and its value was at 105° and 51° for Subject A and C respectively. Further, correlation analysis revealed also that the separation in A-P direction is closely related to wrist extension/flexion at ball contact (r=0.62). The whip-like down-swing of Subject C resulted in 26.9 mm A-P separation, while Subject A had only 8.7 mm at ball contact.

3D kinematic data confirmed that the strategy with larger βs-w-ch and lack of right wrist extension/left wrist flexion at ball contact resulted in a significant decrease in speed of both club head and ball release. This can be clearly illustrated by comparing the down swing of Subject A and C. 3D motion data showed that there was almost no difference of the down swing from highest point to ball contact between both subjects (0.258 s vs. 0.250 s). However, the speed of club head was 33.97 m/s and 38.29 m/s for Subject A and C respectively, a reduction of 12.7% for Subject A. Even a more dramatic difference of 22.5% in ball release speed was confirmed by kinematic analysis (53.15 m/s vs. 65.14 m/s). These results indicated that a whip-like movement will increase the quality of a golf swing.

Empirical data also suggests that trunk rotation is a key for the quality of golf swing. It is the root of trunk-arm system and the whip-like moment should initiate in trunk rotation. However trunk rotation is determined by shoulder and hip coordination. Figure 3 shows that the shoulder-hip coordination of Subject C was more efficient than Subject A, which resulted in more trunk rotation.

Further studies are planned to supply more insight into control patterns. They will focus on the comparisons of novice, advanced and professional golfers to reveal the group differences and to identify parameters that can be effectively used for analysis.

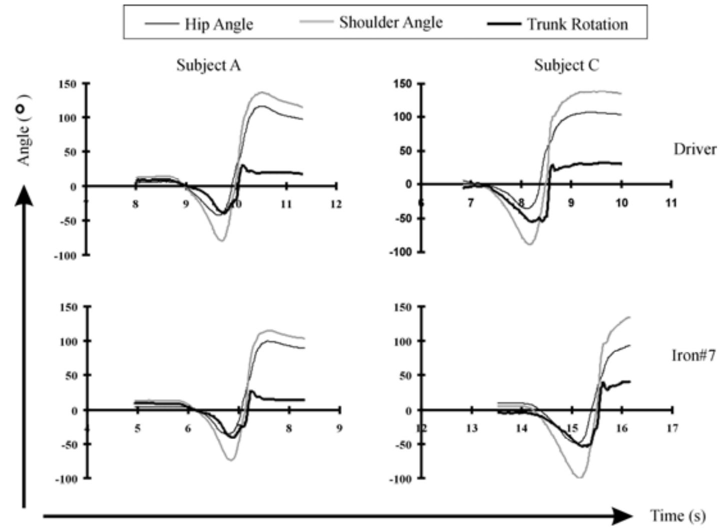


Figure 3: Hip, Shoulder and Trunk rotations during swings

Conclusion: Proper joint control will reduce the dynamic interaction between club and golfer in M-L direction. The whip-like sequential joint control of the Trunk-arm system is a key for increasing ball release speed. Both characteristics can be read by comparing CGRF to COG which supplies an objective way for diagnosing a swing.

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