COMPARISON OF GOLF SWING PATTERNS IN SKILLED FEMALE GOLFERS AMONG THREE DIFFERENT CLUBS

Mutsuko Nozawa, Hiroki Hashimoto, Mitsuo Otsuka, Shinsuke Yoshioka and Tadao Isaka

Faculty of Sport and Health Scicence, Ritsumeikan University, Kusatsu, Japan

The purpose of this study was to compare golf swing patterns using three different clubs among skilled golfers. Five right-handed female professional golfers used their own three clubs (driver, 5-iron, and 9-iron) to hit standard golf balls in our laboratory. 3D coordinates of body and club landmarks during the swing motions were recorded using a 3D motion capture system with operating at 250 Hz frame rates. As the results, the acceleration of club head in each club during downswing reached a maximum around about 0.08 s before impact during similar swing time, and the height of club head at the maximum acceleration showed about 55% of ratio for the body height despite differences of clubs. Skilled golfers therefore might feel as the similar patterns of golf swing even if they are swinging with different length clubs.

KEY WORDS: golf swing, skilled golfers, kinematics.

INTRODUCTION: Any golfers are allowed to use 14 clubs in golf game, and they have to use clubs properly to hit the ball to the right direction and distance with the most efficient motion. Although many golfers can see a huge amount of bewildering information by golf magazines and books, those informations are confusing them.

Several professional golfers and golf teachers stated that the golf swing was identical for club of woods and irons. Some researchers have discussed whether mechanics of golf swing using different clubs performed identical motion (Kaneko & Sato, 1993; Egret, Vincent, Weber, Dujardin, & Chollet, 2003; Ball & Best, 2011). These studies reported similarities or differences of kinematic data.

Although the type of club used might considerably alter the swing motion, golfers might feel that the swing was performed in the same way even if using different clubs. However, golfers have still not understood how to hit a golf ball when using different clubs. Therefore, the clarity of the argument for golfers would be accomplished with provided scientific data.

Previous studies comprehensively evaluated the relative biomechanical variables. However, many questions might be resolved by understanding the acceleration pattern of club head. The purpose of this study was to compare golf swing patterns using three different clubs (driver, 5-iron, and 9-iron) among skilled golfers.

METHODS: Five female professional golfers (164.9±2.6cm; 61.3±5.7kg; right-handed) volunteered to participate in this study. With subjects clad in tight-fitting spandex shorts and tights, the reflective markers were attached to 40 anatomical points. Each subject used their own clubs (driver. 5-iron, and 9-iron) to hit a standard golf ball, and attached some reflective markers. They performed a warm-up, and familiarized themselves with the laboratory environment by hitting balls into a net. The golf balls were hit from a rubber tee by their driver and on an artificial turf mat by other two clubs, into a safety net positioned approximately 3 meters away from the subject in the room. They have been given sufficient practice trials before the data collection, and a ball position of the address was determined beforehand. All subjects were instructed to hit a shot as perfect as possible into the net. Experimental testing consisted of each subject hitting ten full shots with their three clubs. They assessed themselves their all tasks after hitting the ball.

For each swing, the motions of 40 spherical reflective markers were recorded using a 3D optical motion capturing system (Raptor-E digital; Motion Analysis Corp.), consisting 16 cameras, operating at 250 Hz. The three-dimensional marker trajectory of each swing was

modelled using Cortex (Motion Analysis Corp.). The coordinate system was shown in Figure 1.
One of the best golf swing data of three different clubs were selected from the ten trials, and analysed. The swing was divided into two phases by club head movement which defined backswing and downswing. Club head velocity was calculated as resultant velocity by coordinate value of three axes, acceleration was defined as the rate of change with time of club head velocity. Acceleration data were smoothed using a second-order digital Butterworth filter with cut-off frequency set at 8 Hz. Kinematic data were calculated the stance width at the address (Figure 2), and the forward tilt angle (sagittal plane) of upper body in the three events. All data represented the mean value and standard deviation.

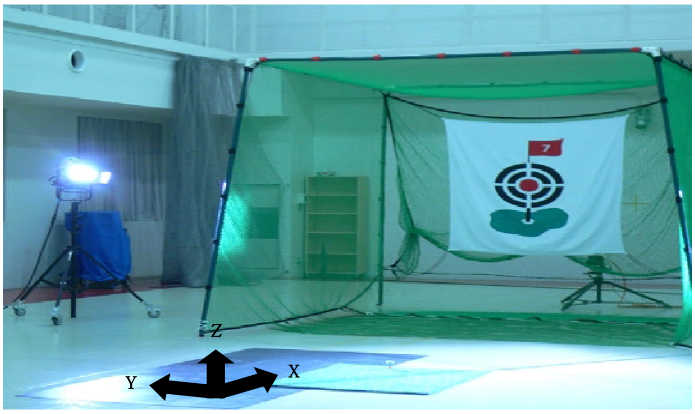

Figure 1: Experimental facility.

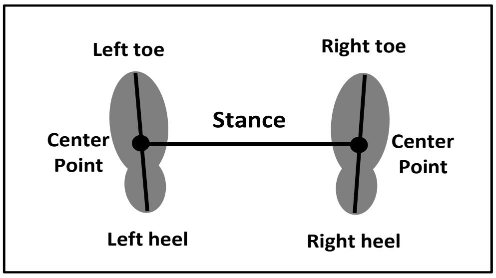

Figure 2: Stance width.

RESULTS: Kinematic data were shown in Table 1. In three clubs, the downswing time of driver was longest, and the maximum club head velocity at the impact was fastest. Acceleration of club head gradually began to increase from the start of downswing. The time-series data of acceleration in three different clubs were shown as a typical example in Figure 3. The maximum value of acceleration in three different clubs appeared nearly simultaneously, and then the acceleration decreased toward the impact.
Figure 4 presented the relationship between the maximum acceleration and that appearance time in three different clubs. The mean value of maximum acceleration values in three different clubs were provided in Table 1. The mean value of appearance time in three different clubs were 0.086±0.006 sec in the case of driver, 0.082±0.007 sec for 5-iron, 0.082±0.005 sec for 9-iron, respectively.
The height of left hand at the time of maximum acceleration was normalized by each subject's body height. Those values were presented by percentage, 57.3±2.2% in the case of driver, 54.8 ±2.3% for 5-iron, 52.9 ±2.2% for 9-iron.
Stance widths at the address were shown in Table 1. Ratio for the height of the stance width indicated the percentage, 30.2 ±2.6 % in the case of driver, 26.8 ±2.7 % for 5-iron, 26.0 ±2.0 % for 9-iron. Forward tilt angle of upper body changed during golf swing. Angle change in the three events shows in Figure 5.

Table 1: Kinematic data in three different clubs.

Clubs	Backswing time (sec)	Downswing time (sec)	Maximum club head velocity at the impact (m/sec)	Maximum acceleration (m/sec^2)	Stance width (cm)
Driver	1.22±0.08	0.33±0.05	40.2±1.3	219.0±13.6	49.7±4.0
5-iron	1.12±0.09	0.32±0.04	29.7±0.9	175.8±10.4	44.2±4.4
9-iron	1.20±0.11	0.31±0.05	28.1±0.6	167.8±11.6	42.9±3.2

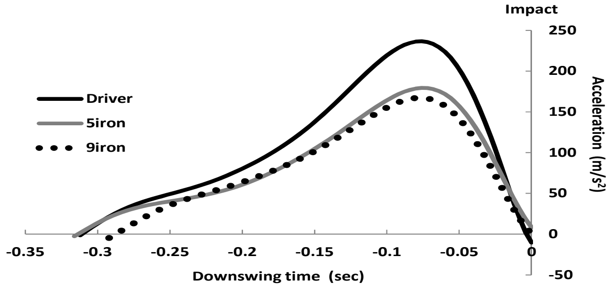

Figure 3: Acceleration pattern of club head from the top of backswing to the impact showed representative example.

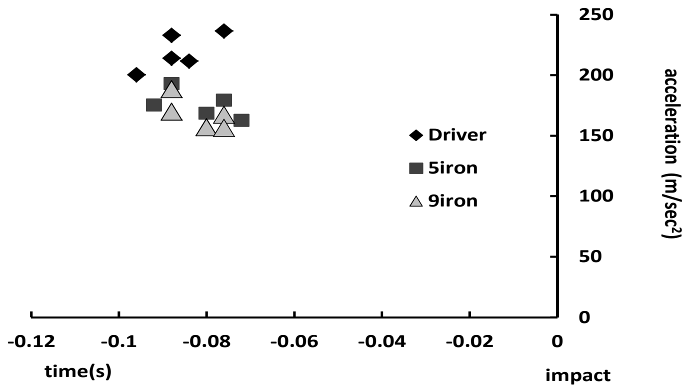

Figure 4: Relationsip between the maximum acceleration and the appearance time in three different clubs.

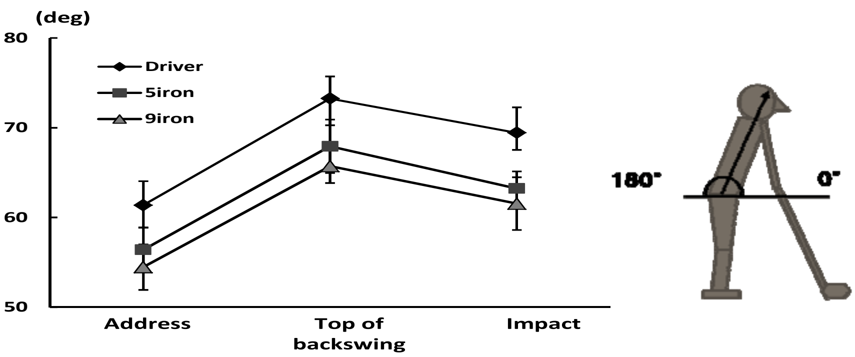

Figure 5: Forward tilt angle of upper body in the three events showed mean value and standard deviation, respectively.

DISCUSSION: The purpose of this study was to compare golf swing patterns using three different clubs among skilled golfers. Especially, we focused attention on the club head during downswing. The three clubs used in this experiment had differences of the length or other of physical characteristics. Consequently, the trajectory of club head was predicted to be different in each club.

Although shorter downswing time is one of key factors to get faster club head velocity at impact, the downswing time of three clubs demonstrated similar time in this study. However, the club head velocity at the impact indicated significant difference among three different clubs. These results suggested that the golf swing motion time was not affected by the physical characteristics of golf club.

The acceleration of club head during downswing gradually increased from the downswing start. The time series variation of 5-iron and 9-iron showed similar tendencies. On the other hand, the time series variation of driver increased more rapidly than other clubs from 0.2 sec before the impact. Furthermore, maximum acceleration of the driver showed the highest

value among three different clubs (Table 1). These results might be caused by characteristic of driver; whose length was about 20 cm longer than those of the other two clubs.
The acceleration of club head in each club during downswing reached a maximum around about 0.08 sec before impact. These tendencies were occurred in all subjects. Even if the golfers use different length of the clubs, they might feel similar the temporal change of club head acceleration.
Surprisingly, the height of left hand at the maximum acceleration showed about 55% of ratio for the body height, and these values were similar to height of center of gravity position in body's static balance. All subjects showed these phenomena that mechanism could not understand.
The stance width increased with the length of the club. These results are in agreement with the study of Egret et al. (2003), though the method of measurement is accompanied by some differences. Transfer weight during golf swing would be executed correctly by maintained static balance in the address (Hume, Keogh, & Reid, 2005). It is reasonable to suppose that golfers adopted appropriate stance width to get pursued distance in each club.
Forward tilt angles of upper body in three different clubs changed at three events. Golfers bend their trunk forward because they must hit the ball on the ground. However, forward tilt angle of upper body did not maintain from the address to the impact. These changing angles were not only derived from the physical characteristics of golf club, but also golfers' swing motions.

CONCLUSION: Many skilled golfers and golf teachers have stated that the golf swing was identical for every clubs. However, several researchers reported that the differences of golf swing patterns using different clubs were due to the physical characteristics of golf club. In this study for these two different views, golfer's postures at the address in three different clubs were due to the physical characteristics of golf club. However, the maximum acceleration in three golf clubs had occurred nearly simultaneously at similar swing timing, and then the displacement of club heads heights were also similar. Therefore, even if the golfers are swinging with different length clubs, they might feel as the similar golf swing patterns.

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