GENERAL CHARACTERISTICS OF SWING MOTION IN PROFESSIONAL AND AMATEUR FEMALE GOLFERS

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INTRODUCTION

When playing golf, most important factor to determine a good performance may be “accuracy” in controlling the direction and distance of the struck. Further, distance particularly with a drive between the pelvis and mid-thoracic spine, Mac Teigue et al (1994) tested more than 100 PGA and Senior PGA Tour professional golfers, using a training machine called a Swing Motion Trainer (STM) that was mounted on the back of the subjects. Earlier studies also employed professional golfers were used as subjects, and analyzed the golf swing from various points of view (cf., Carlss, 1967; Neal and Wilson, 1985). In the present study, we attempted to elucidate the general characteristics of golf swing motion in female professional and amateur golfers. For this purpose kinematical parameters were analyzed three dimensionally during performance of a drive shot using two high speed video cameras.

METHODS

The subjects were 37 right-handed female golfers, comprised of 18 professional tournament golfers (G-pro) and 19 amateur golfers (G-ama). The professionals all belonged to the LPGA; and the handicaps of the ranged from 20-25. Subject body height, weight, and muscle strength measurements are shown in Table 1. For the experiment, each subject performed a drive shot several times indoors into a safety net. Prior to the experiment, 54 control points were recorded on videotape. Marks were attached to 25 points on the body and club-head, and displacement of each mark was recorded at 200 fps using 2 high speed video cameras, which were synchronized using a Nac system. Analysis was made for the best shot, which was selected by each subject. During processing of the date, the digitized variables were smoothed out with a second order Butterworth digital filter with a cutoff frequency of 15 Hz. The direction of the shot was defined by the anterior-posterior direction, X, lateral direction, Y, and vertical direction, Z. The mechanical parameters were digitized using a DLT method.

<table>
<thead>
<tr>
<th>Mean±S.D.</th>
<th>Pro</th>
<th>Ama</th>
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<tbody>
<tr>
<td>Height (cm)</td>
<td>161.9±4.9</td>
<td>157.2±5.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.6±5.0</td>
<td>53.6±6.0</td>
</tr>
<tr>
<td>Back strength (kg)</td>
<td>105.7±17.1</td>
<td>72.8±20.0</td>
</tr>
<tr>
<td>Grip Right (kg)</td>
<td>37.8±6.0</td>
<td>29.5±4.5</td>
</tr>
<tr>
<td>Grip Left (kg)</td>
<td>38.7±5.5</td>
<td>27.0±4.0</td>
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</table>

RESULTS

Club-head velocity and acceleration:

The experiments were conducted indoors, thus, instead of the distance; club-head velocity (CHV) was taken as a false criterion. The maximal values for CHV were 39.1± 1.3 m/s for G-pro and 30.6±2.7 m/s for G-ama, which were significantly different (p < 0.001). As for the time course, CHV during the early phase of the downswing was greater in G-ama than in G-pro, whereas this relation was reversed (G-pro>G-ama) in the latter stage. The time point when the CHV curves of both groups crossed each other was 0.01 seconds before impact, which is abbreviated as ‘Vc’ afterward. CHV attained the maximum at the time of impact in both groups (Figure 1, upper frame), which indicates that the club-head was accelerated rapidly before ‘Vc’ in G-pro, whereas it decreased before Vc in G-ama. The peak values of acceleration were 201.8±37.2 m/s² and 141.8± 44.3 m/s² in G-pro and G-ama, respectively. The peak value appeared later in G-pro than in G-ama; 0.08 seconds and 0.1 seconds respectively before impact (Figure1, lower frame).

Table 1: Subject body height, weight, muscle strength measurements.

Figure 1: Velocity and acceleration of the club-head during downswing.
Rotation of hips and shoulders:
The rotation angle between the hips and shoulders was defined as that to the target line with backward considered negative (-) and forward positive (+). The angle of the hips at the top of the swing, tended to be greater in G-pro (-43.5±5.5°) than in G-ama (-39.0±12.2°), although difference was not statistically significant. On the other hand, at the time of impact, the hip angle in G-Pro was significantly greater (45.5±7.5°) than that in G-ama (16.8±19.8°), as was the range of motion (ROM) for hip rotation G-pro, (88.9°) vs. G-ama (55.8°). Similar to the hips, the angle of the shoulders at the top of swing tended to be greater in G-pro (-114.6±5.7°) than in G-ama (-110.7±11.6°), though the difference was not significant. However, G-pro showed significantly greater shoulder rotation angle at impact (25.7±7.7°) than G-ama (7.4±14.8°), thus, ROM for the shoulders was significantly greater in G-pro (140.3°) than in G-ama (118.1°).

Angles of wrist, elbow, and left arm:
The wrist-cock angle (inside angle) at the onset of the downswing was 86.0±13.5° in G-pro and 99.4±11.9° in G-ama. This wrist-cock angle in G-pro decreased to the minimum during downswing and increased until impact. On the other hand, the wrist-cock angle in G-ama remained relatively constant during downswing, and then increased to the time of impact. The minimum wrist-cock angle was significantly smaller in G-pro (79.1±15.0°) than in G-ama (97.3±14.1°) (p<0.001), while the wrist-cock angle at impact was also significantly smaller in G-pro (133.6±6.7°) than in G-ama (139.0±8.7°) (p<0.05).

As for the right elbow joint, G-pro tended to extend the angle during the early phase of the downswing. Conversely, G-pro did not extend the elbow at impact, as compared with G-ama, though the differences between groups were not significant. For left arm movement around the shoulder joint, horizontal position was defined as 0. As a result, the left arm angle at impact was greater in G-pro (95.6±9.6°) than in G-ama (87.4±6.7°).

Angular velocities of hips, shoulders and wrist:
During the later half of the downswing, G-pro increased the hip rotation velocity first, then shoulder rotation velocity increased. The drastic acceleration of the shoulder rotation (upper torso rotation) took place when the hip rotation velocity reached its maximum. The velocity at the wrist joint (uncocking) continued even after the hip and shoulder rotation velocities ceased to increase and continued up to just before impact. This series of velocity changes was observed in G-pro, but not clearly detected in G-ama (Figure 2).

DISCUSSION
The results obtained in the present study may not be novel, however, our purpose was to elucidate a general characterized swing motion of professional golfers. Thus, the kinematic parameters including time processes were averaged to statistically compare professionals and amateurs.

For performance of a drive shot, distance and correct direction are both important results. To achieve satisfactory distance, CHV at impact must be at a high level. As such, CHV may be strongly influenced by skill-related and physical fitness related factors. In regard to the latter, significant correlations between CHV and back strength (Kawashima, 1981) and between CHV and body twisting torso strength (Inoue and Kaneko, 1999) have been reported. In the present study, there were significant correlations between CHV and either morphologic measured or muscle strength in the total date from both groups (Table 1). However, when the 2 groups were considered independently, no significant correlation was suggesting the importance of skill-related factors.

![Figure 2: Angular velocities in the hip, shoulder, and wrist cock during the downswing.](image-url)

At the onset of the downswing, the CHV of G-pro was somewhat slower than that of G-ama, which might have been due to the fact that G-pro did not uncock as much as G-ama during the initial downswing movement. In contrast, during the latter half of the downswing phase, the CHV of G-pro increased drastically and exceeded that of G-ama, which resulted in a maximum CHV that was 27% greater in G-pro. The difference in time course of CHV between 2 groups seemed to be related to skill factors, while it is interesting to note that the standard deviation of CHV (vertical lines in Fig.1) was smaller in G-pro than in G-ama, particularly near impact. The time when the rotation velocity of the hips in G-pro exceeded that in G-ama was coincident with the time when the CHV of G-pro exceeded G-ama. This synchronous timing may suggest a strong influence of the hip rotation velocity on CHV, even if it occurred by chance. Further, CHV was at maximum speed at time when the shoulder rotation reached its maximum point, suggesting the importance of shoulder rotation on CHV. This may be the effect of force developed by twisting the torso above the hips, since peak shoulder rotation velocity at the time of peak CHV. These phenomena were particularly remarkable in G-pro.
displacements (phase shift) by the hips and shoulders. The ROM was significantly greater in G-pro than in G-ama, as the hips and shoulders of G-pro were 1.6 and 1.2 times greater, respectively, than those of g-ama. Differences in ROM between the two groups were not due to the angle at the top of swing, but rather to the angle at impact, during which G-pro hit the ball with the hips rotated to $45^\circ$, and G-ama rotated the hips to only $17^\circ$. Likewise, the shoulder angles were $26^\circ$ and $7.4^\circ$ in G-pro and G-ama respectively at impact, showing that the attitude of the body was more twisted in G-pro than in G-ama. As reported by McTeigue et al (1994), the greater torso rotation in professional golfers is considered to be one of the most important factors to produce high velocities of the clubhead and ball velocities at impact. Sanders and Owens (1992) studied the focal point of swing (‘termed as ‘hub movement’), in which they quoted Leadbetter’s words that the club-head rotates about the right shoulder on the back swing and rotates around the left shoulder during the downswing. Calsoo (1967) observed marked EMG activities related to the shoulder joint as motion shifted from left to right when the swing changed back swing to downswing. In the present study, the left arm in G-pro rotated at the shoulder more than in G-ama, the angle of the left arm at impact was approximately $96^\circ$ in G-pro and $87^\circ$ in G-ama. These results show that G-pro struck the ball the left arm position had passed $90^\circ$, whereas G-ama hit prior to $90^\circ$. The velocity of the arm swing at the shoulder joint was also greater in G-pro, as were hip and shoulder velocities.

Cocking at the wrist joint was one of the most remarkable characteristics seen in the professionals. Uncocking in G-pro started from a much shallower cock angle, and its velocity reached a 40% greater peak value than in G-ama. We found that peak angular velocity appeared in order of the hips, shoulders and wrists (uncock) in G-pro. However, this order of event was not clearly demonstrated in G-ama (Figure 2). To account for this phenomenon, double-pendulum (Neal and Wilson, 1985) and tri-pendulum (Campbell and Reid, 1985) models have been considered. Cochran and Stobbs (1968) also discussed so-called ‘whip-like action’. A pendulum model may useful to explain energy flow the proximal part to the distal part of the limbs, which was demonstrated by the professionals and seemed to be one of the most important general characteristics differentiating the two groups in the present study.

**SUMMARY**

To elucidate the characteristics of professional golfers, drive shots by 18 professional and 19 amateur female golfers were analyzed three dimensionally. We found that the significantly higher club-head velocity produced by the professionals was associated with a greater range of torso rotation and higher velocities by the hips and shoulders as they rotated during the downswing. Further, wrist cock angle was much more acute in the professionals. The angular velocities increased in the order of hips, shoulder, and wrist (uncocking) in the professionals, suggesting that professional golfers perform a drive shot using a ‘whip-like action’.

**REFERENCES**
