THE CONTRIBUTION OF JOINT TORQUE TO THE ACCELERATION OF THE CLUBHEAD DURING THE DOWNSWING PHASE IN GOLF: A CASE STUDY

Atsushi Okamoto[1]

Faculty of Sport and Health Science, Tokai Gakuen University, Miyoshi, Japan[1]

The purpose of this study was to investigate the contribution of joint torque to the acceleration of the club during the downswing phase in golf. Three professional golfers volunteered as participants (age: 37.7 ± 4.5 years, height: 1.70 ± 0.03 m, weight: 63.3 ± 4.3 kg). Their driver shots were recorded using a 10-camera (250 Hz) VICON system. The forces and torques applied to their drivers during the downswing phase were calculated based on Newton-Euler equations. Joint force power and joint torque power were also calculated. The mechanical work was obtained as an integral value of the power during the downswing phase. The mechanical work done by the joint torque accounted for about 15% of the total mechanical work in the downswing phase. Therefore, these results suggest that the grip torque applied to the club plays an important role in power generation in a golf swing.

KEY WORDS: Golf swing, Joint torque, Contribution.

INTRODUCTION: The speed of the clubhead at impact is the principal factor which determines the distance that a golf ball will travel. Over the years, golfers have debated whether the action of the wrists should be passive or active in the releasing of the clubhead prior to impact. Most golfers have an intuitive belief that the addition of properly timed muscular torque at the wrist joint will increase clubhead speed at impact. However, a number of pundits believe the opposite is true. Williams (1967), who worked from a stroboscopic photograph of Bobby Jones' swing, concluded that the uncocking torque applied by the hands was negligible. On the other hand, Sprigings and Neal (2000) described through a simulation study using a model as a three-segment, two dimensional, linked system that significant gains in clubhead speed (≈9%) could be achieved if an active wrist torque was applied to the club during the latter stages of the downswing. Therefore, the purpose of this study was to investigate the contribution of the joint torque applied to the golf club to the acceleration of the clubhead during the downswing phase.

METHODS: Three professional golfers volunteered to participate in this study (age: 37.7 ± 4.5 years, height: 1.70 ± 0.03 m, mass: 63.3 ± 4.3 kg). A 10-camera (250Hz) VICON system was used to capture 3D trajectories of 54 reflective markers attached to each golfer's body and the driver (14mm diameter). For testing sessions, each golfer performed 5 shots into a target net 5 m away (Figure 1). The fastest of the 5 shots of each participant was analysed. The inertial properties of the club were measured using standard pendulum techniques. The arm segment assumed a single rigid body. The arm segment and the club was connected to the centre of the left and right hand. The coordinate system of the club is shown in Figure 2. The joint forces and torques applied to the golf club during the downswing phase were calculated based on Newton-Euler equations. The joint forces and torques were interpolated by cubic spline function and the mean ± SD were calculated at each relative time of the downswing phase. The joint forces and torques just before impact could not be calculated due to the influence of the shock at impact. Mechanical work was calculated by integreted joint power.

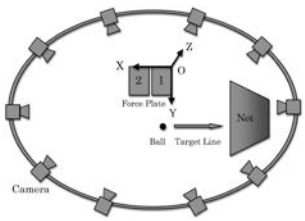

Figure 1: Experimental set-up.

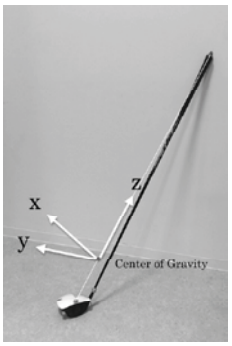

Figure 2: Coordinate system of the club.

RESULTS: The maximum clubhead speed during the downswing phase was 45.8 ± 1.7 m/s (Table 1). Figure 3 shows the average value (±SD) of the joint forces applied to the golf club. The force was mostly generated around the Z-axis. The maximum value of the force was 339.5 ± 12.2 N around the Z-axis at 95% time in the downswing phase. Figure 4 shows the average value (±SD) of the joint torques applied to the golf club. At first, the torque was observed mainly around the X-axis, and finally the maximum torque was observed around the Y-axis just before impact. These changes in torque toward the ball along the swing plane during the latter stages of the downswing may occur as the clubface rotates. The maximum value of the torque was 40.9 ± 2.9 N•m at 87% time in the downswing phase. These results suggest that the active wrist torque that was applied to the club during the downswing phase gains in higher clubhead speed at impact.

Table 1
Maximum clubhead speed and time of the downswing phase

Subj.	Head Speed (m/s)	Time of the downswing phase (sec)
1	47.8	0.28
2	46.0	0.26
3	43.7	0.30
Mean	45.8	0.28
SD	1.7	0.02

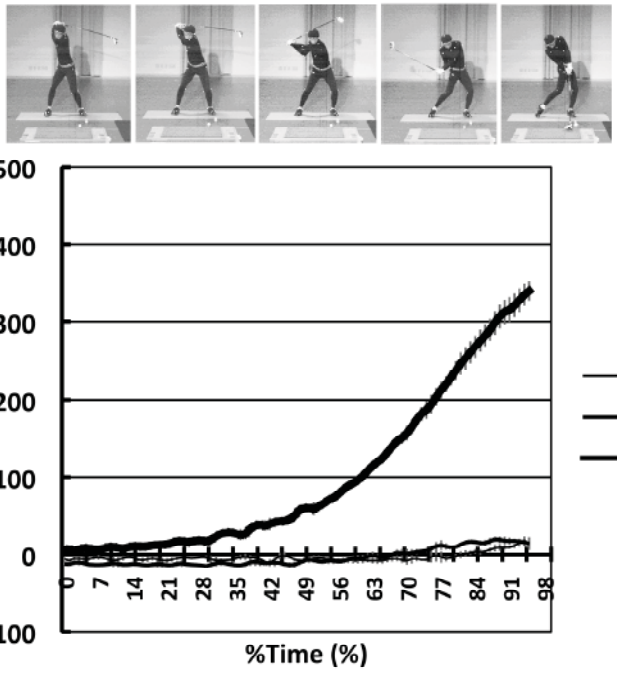

Figure 3: The average value (±SD) of the joint force during the downswing phase.

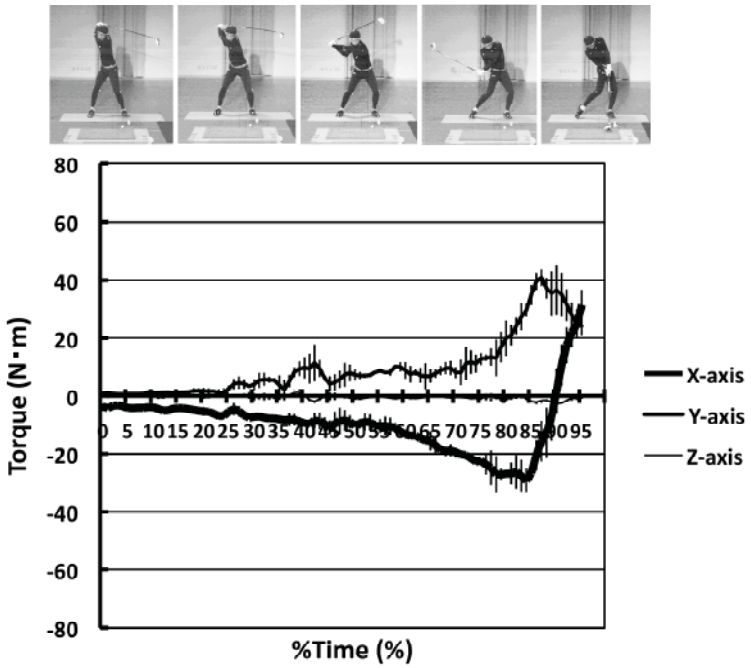

Figure 4: The average value (±SD) of the joint torque during the downswing phase.

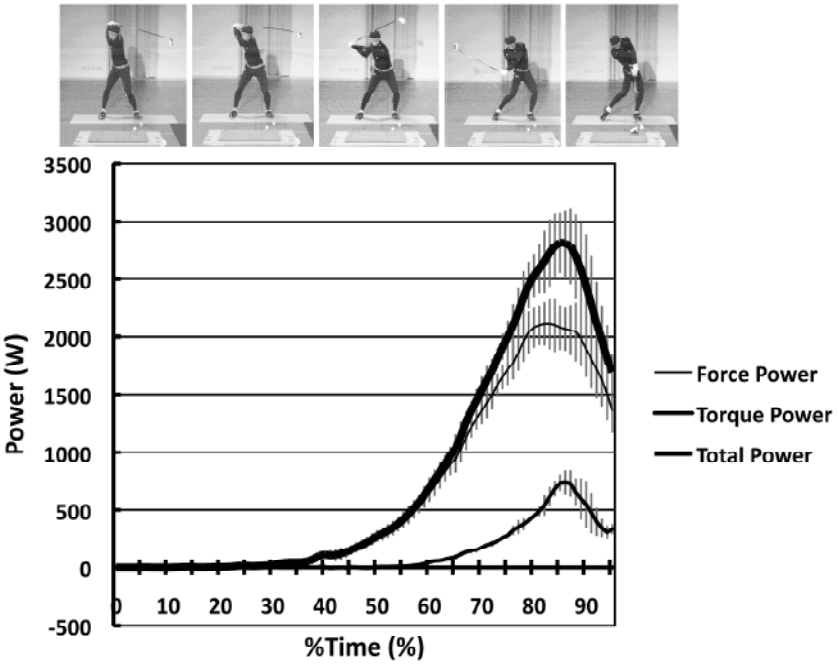

Figure 5: The average value (±SD) of the joint power during the downswing phase.

Table 2
The mechanical work done by the joint during the downswing phase

Subj.	Work by the force(J)	Work by the torque(J)	Total work(J)
1	195.1	39.9	235.1
2	181.9	33.8	215.7
3	169.2	19.6	188.8
Mean	182.1	31.1	213.2
SD	10.6	10.4	23.3

Figure 5 shows the average value (±SD) of the joint power applied to the golf club during the downswing phase. The maximum value of the force power, torque power and total power was 2113.4 ± 260.7 W at 83% time, 737.9 ± 104.2 W at 86% time and 2813.4 ± 216.9 W at 85% time in the downswing phase, respectively. The mechanical work done by the joint during the downswing phase is shown in Table 2. The mean value of the maximum total work was 213.2 ± 23.3 J. The mechanical work done by the joint torque in the total mechanical work was about 15%.

DISCUSSION: In the golf swing, the golf club will accelerate by joint force and torque. Consequently, the mechanical energy of the club will increase. Therefore, it is important to consider the joint force power and joint torque power. In this study, the contribution of the joint force power and joint torque power was evaluated as the mechanical work done by the joint applied to the golf club during the downswing phase (Stefanyshyn, D.J. and Nigg, B.M., 1997). The results showed that the contribution of the mechanical work done by the joint torque accounted for about 15% of the total mechanical work in the downswing phase. Moreover, plenty of joint torque power was generated in the last quarter of the downswing phase. This clarifies that the motion from the halfway down to the impact is the most important in the joint torque power generation.
Williams (1967) denied the increasing of the clubhead velocity was due to uncocking torque. Furthermore, Vaughan (1981) stated “The downswing was initiated by pulling along the length of the shaft, and applying a positive hand torque. As the swing progressed, force increased markedly while torque was applied in the opposite direction.” However, in this study, joint torque power indicated a positive value in the latter half of the downswing. On the other hand, many simulation studies of golf swing did not consider joint torque, e.g. Miura’s parametric acceleration (2001). Though, in this study, the mechanical work done by the joint torque accounted for about 15% of the total mechanical work in the downswing phase. Therefore, these results suggest that the torque applied to the club plays an important role in the power generation of each golf swing.

CONCLUSION: In the present study, the contribution of joint torque to the acceleration of the club during the downswing phase in golf was investigated. The results revealed that active wrist torque during the downswing phase was important in generating higher clubhead speed at the impact.

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