

## THE ENERGY CONVERSION EFFICIENCY OF DRIVER SHOT IN FEMALE PROFESSIONAL AND AMATEUR GOLFERS

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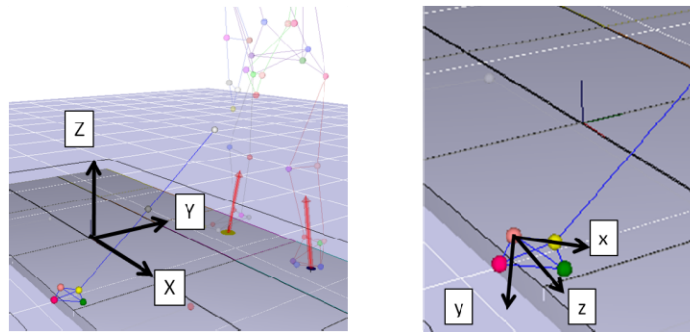
The purpose of this study was to evaluate the performance of driver shot from the viewpoint of the energy conversion efficiency between club head and ball at impact. Six female professional golfers and six female amateur golfers participated in this study. All subjects were instructed to hit a straight ball with their usual swing. Each subject performed ten trials. Three dimensional coordinates of reflective markers attached on a body and club landmarks were obtained using the motion capture system operating at 250 Hz. High speed camera was used to measure the movement of the club head and ball. The energy conversion efficiency was significantly different between professional and amateur golfers ( $p < 0.01$ ). This result suggests that not only club head speed but also the energy conversion efficiency are important for driving distance.

**KEYWORDS:** female professional golfers, driver shot, energy conversion efficiency.

**INTRODUCTION:** Golf is a game of playing a ball with a club from the tee to the hole with as few shots as possible. In golf, a tee shot can have a large effect on golf performance where the aim of the game is to hit the golf ball into the hole. The driver shot is most used shot from the tee and the primary goal of the driver shot is to hit the ball as far as possible while maintaining accuracy. There are five parameters that affect the ball flight: club head speed, centeredness of contact, club head path, clubface position and angle of approach (Hellstrom, 2009). However, these definitions do not adequately explain ball flight. It has been reported that contact time with the club head and the ball at impact is about 400 $\mu$ s (Williams & Sih, 2002), and it was considered that club head behaviour affects ball flight during this time. In a previous study, it was reported that the 3D mechanics of the golf swing using the energy based approach to investigate the work of the body joints and the club (Nesbit & Serrano, 2005). However, the change of the energy from club head to ball at impact had not been reported.

The purpose of this study was to evaluate the performance of the driver shot by energy analysis for the club head and the energy conversion efficiency between club head and ball at impact in female professional and amateur golfers.

**METHODS:** Six female professional golfers (41.4  $\pm$  7.4 y, 163.6  $\pm$  3.4 cm, 60.2  $\pm$  5.4 kg, right-handed) and six female amateur golfers (47.8  $\pm$  5.2 y, 159.5  $\pm$  5.3 cm, 51.5  $\pm$  5.5 kg, handicap 8.3  $\pm$  1.6, right-handed) volunteered to participate in this study. The reflective markers were attached to 40 anatomical points. Each subject then familiarized themselves with the laboratory environment by hitting golf balls from a rubber tee embedded in an artificial turf mat into a net approximately 3m away. Subjects were instructed to hit with their own driver as straight as possible and performed 10 shots. During the driver shots, 3D coordinates of body and club landmarks were obtained using a motion capture system (Raptor-E digital; Motion Analysis Corp.), consisting 16 cameras operating at 250 Hz. A high speed camera (MEMRECAM fkK5; nac Corp.) was used to measure the movement of the ball from pre-impact to post impact at 10,000 Hz. The 3D marker trajectory of each swing was modeled using Cortex (Motion Analysis Corp.). The global coordinate system is shown in Figure 1. The local coordinate system was defined for the club head from groups of three adjacent marker locations (Figure 1).



**Figure 1: Global coordinate system and local coordinate system.**

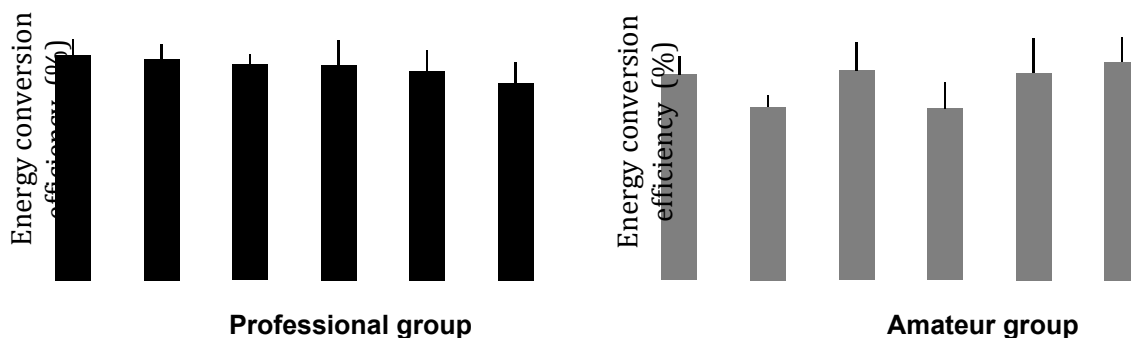
The translational kinetic energy, the rotational kinetic energy, the potential energy of the club head was obtained from each coordinate system with energy calculation formulae. The total energy of the club head is the sum of kinetic and potential energy.

The energy conversion efficiency between club head and ball at impact is defined the percentage of the translational kinetic energy of the ball about the decrease of the amount of club head energy at impact.

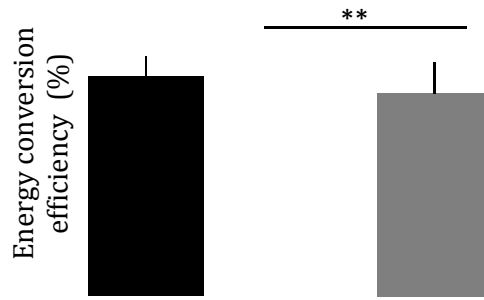
**RESULTS:** No significant differences in age, height and body mass between professional and amateur golfers were found. However, professional golfers had greater club head and ball speed compared to amateur golfers (Table 1). The energy conversion efficiency of each subject and group is presented in Figures 2 and 3.

**Table 1: Physical and general swing characteristics of professional and amateur golfers.**

	Professional(n=6)	Amateur(n=6)	Significance
Age(years)	40.7±8.1	47.8±5.2	ns
Height(cm)	163.1±3.8	159.5±5.3	ns
Body mass(kg)	59.1±4.8	51.5±5.5	ns
Club head speed(m/s)	38.0±0.8	34.9±1.0	p<0.01
Ball speed(m/s)	50.3±1.9	45.6±2.4	p<0.01



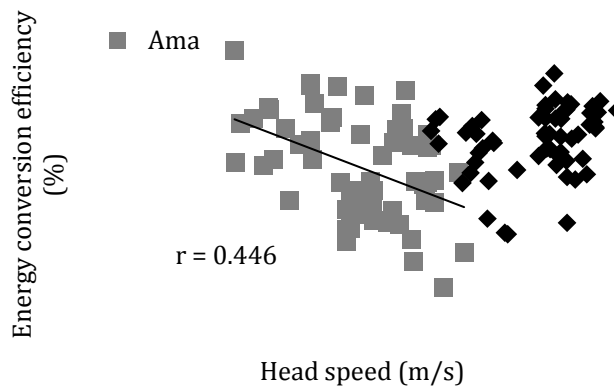
**Figure 2: Energy conversion efficiency.**



\*\*Significant difference ( $p < 0.01$ ) between groups.

**Figure 3: Comparison of professional and amateur golfers.**

We found that both clubhead speed and ball speed of the professional golfers was significantly greater than the amateur golfers. We also found that the energy in the club head mainly consisted of transitional kinetic energy (99.6%), while the effects of rotational kinetic energy and potential energy were small. The energy conversion efficiency of the professional golfers group was  $71.9 \pm 6.8\%$ , and amateur golfers group was  $66.9 \pm 10.0\%$ . The energy conversion efficiency of professional golfers was significantly greater than that of the amateur golfers ( $p < 0.01$ ).



**Figure 4: Correlation of energy conversion efficiency and club head speed.**

The relationship between energy conversion efficiency and club head speed is presented in Figure 4. It was showed that both the energy conversion efficiency and club head speed of professional golfers was greater than those of amateur golfers, and the variability of the professional golfers was less than that of amateur golfers. Although the energy conversion efficiency of amateur golfers tended to decrease with increasing head speed, those of trend were not seen in professional golfers ( $r = 0.446$ ,  $p < 0.01$ ).

**DISCUSSION:** There are few studies that have examined the effect of skill levels on energy (Nesbit & Serrano, 2005). Results from the present study revealed transference of energy from the club head to the ball as the energy conversion efficiency. For both club head speed and energy conversion efficiency, professional golfers performed better than the amateur golfers. It is suggested that professional golfers were not only able to store translational kinetic energy in the club head during the downswing but also convert the energy of the club head to the energy of the ball. The results suggested that there were many factors to determine the energy conversion efficiency and they were different for club head speed. Impact position on the club face was considered as one of the major factors for energy conversion efficiency. In this study, we were able to measure the reproducibility in all subjects to perform 10 driver shots. Professional golfers are able to maintain high values of

energy conversion efficiency during 10 driver shots by impact near the center of the club face. On the other hand, the impact position of amateur golfers is not as stable.

**CONCLUSION:** This paper presented a study of the energy conversion efficiency at impact by using energy analysis in professional and amateur golfers. The differences between both groups existed in club head speed, the ball speed and energy conversion efficiency. A confirmed hypothesis in the current study was that skill level differences of golf emerged for energy conversion efficiency. This energy approach in a club and ball determined the new factor of golf performance parallel to the head speed. It is necessary for progress in driver shot performance to improve both energy conversion efficiency and club head speed. The energy conversion efficiency made it possible to describe and characterize the impact of professional and amateur golfers, and to identify how differences may be impacted by skill level.

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