IMPACT ANALYSIS OF GOLF STROKES BY MEANS OF 3D MOTION CAPTURING

[1] Stefan Zunzer, [1]Claus Cagran, [1]Philipp Huber and [1]Wolfram Müller
[1]Human Performance Research Graz, Max-Mell-Allee 11, 8010 Graz, Austria,
Email stefan.zunzer@stud.meduni-graz.at, web: hpr.uni-graz.at

INTRODUCTION

Golf is a popular activity for both men and women and, in one form or another, has been around for over five hundred years. It can be assumed that even during the very early stages of the game, players, especially those with a scientific inclination, were curious as to the behavior of the ball and clubs, and experimented on ways to improve their performance [1, 2]. However, a recent search through major online literature databases showed no relevant results for measured impact analysis data. The purpose of this study was to test the applicability of 3D motion capturing data for impact analysis (momenta and energies) of golf strokes.

METHODS

Four young golf players (age: 24.5 ± 3.3 yrs; height: 178.6 ± 7.1 cm; weight: 72.5 ± 10.3 kg) participated in this study: Two pro players with handicap (HCP) 0, one female player with HCP 6.7, and one high HCP-player with HCP 32.5.
A VICON V612 3D motion capturing system with 8 M2-cameras at 500 Hz was used to trace the movement of the player and the equipment. The golf club was equipped with two markers on the shaft and three on the club head. The ball was covered in a thin reflective layer, acting as one single marker. Markers were also attached to the players, but these data were not used for the current analysis. Three velocity components (in Cartesian coordinates) can be calculated based on the time-dependent 3D coordinates of each marker. The measurement was set up indoors and each test person performed a set of three strokes [3].

RESULTS AND DISCUSSION

For an impact analysis the velocities and masses of the club head and the ball have to be measured. Since the highest ball velocity (v_b) after impact was found to be 70 m/s and remained constant with a standard deviation of 0.67 for the entire detected flight distance (about 3.5 m), linear momenta and kinetic energies of the ball can be precisely determined. The mass of the covered ball was 48.89 g (± 0.01 g), aerodynamic drag is negligible, thus the uncertainty of the linear momentum yields $\delta p = \pm 0.2$ kg·m/s and $\delta E_{kin} = \pm 6.7$ J for the energy.

In contrast, the determination of the club head velocities (and thus momenta and energies) turned out to be more difficult for the following reasons:

a) Unlike the ball, the club head is not at rest before the impact, but accelerated and reaches maximum speed at time of impact. At the impact, energy is transferred to the ball (in about 480 µs [1]) and club head velocity suddenly decreases; a velocity difference Δv needs to be detected and errors may accumulate.

b) As club head velocities before impact are lower than typical ball speeds, the same spatial measurement resolution leads to larger uncertainties for velocities.

c) The three markers on the head (spherical, 14 mm diameter) are elevated by another 2 mm (mounting support) and encounter accelerations of about $20 \cdot 10^3$ m/s² at impact. This may result in displacements up to several mm (estimated) and decreases localization accuracy (or even leads to breakage of the marker support). A possible solution in preparation is to cover the club head (or sections thereof) with a reflective layer (like the ball) to act as one large marker. This should resolve the displacement problem and increase spatial localization.

The calculation of momenta and energies showed reasonable results for some subjects ($\delta p = \pm 0.23$ kg·m/s) and failed for others ($\delta p = \pm 0.72$ kg·m/s). In addition to velocity errors, linear momenta are also affected by the club head mass which cannot be measured directly (head attached to shaft). Manufactures do only state ‘typical’ head weights. The individual influence of the shaft and its physical properties (stiffness, weight, etc.) is unknown. During the impact a fraction of the shaft weight has to be added to the head weight, yielding an effective mass (m_{eff}).

As soon as the club head velocity measurements are improved, the conservation of momentum can be used to determine this effective club head mass.

CONCLUSION

The ball velocities, momenta, and energies after impact can be accurately obtained with the use of motion capturing setup. Marker displacement of the club head during impact and unknown m_{eff} led to inconclusive results. After improvement of the club head speed measurement, conservation of momentum allows calculation of m_{eff} and to study the influence of shaft properties, stroke techniques, and different player skill levels on the impact.

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