Nils Betzler[1], Stefan Kratzenstein[1], Fabian Schweitzer[1], Gongbing Shan[2], Kerstin Witte[1]

[1]Department of Sport Science
University of Magdeburg, Germany

[2]Department of Kinesiology
University of Lethbridge, Canada

3D Motion Analysis of Golf Swings

Development and validation of a golf-specific test set-up

Introduction

Motion analysis methods have been used in the past to analyse various aspects of the golf swing (e.g, Burden et al. 1998). In many cases, however, the swing characteristics have been studied using 2D techniques only. Only few studies include 3D, full-body recording of the golfer's motion during the swing and no established standards or recommendations for full body analyses of golfers could be found.

Therefore, the aims of this study were:
(1) to analyse the needs of 3D full-body motion analysis in golfing, and
(2) to develop and validate a golf-specific 3D motion analysis test set-up.

Methods

From preliminary tests and the characteristics of a typical golf swing, five main difficulties for 3D motion analysis of golf swings were identified (see Tab. 1). A specific test set-up was developed to address these problems (see Fig. 1). A motion capture system (Vicon v8i, 12 cameras, 250 Hz) recorded the motion of 48 markers placed in anatomical positions and on the shaft (see Fig. 2). The markers on the left and right humerus, forearm, femur, and tibia were placed on 100 mm sticks (see Fig. 3). To reduce marker accumulation in the hands/wrists area, the number of these markers was reduced.

In order to validate the test set-up, two advanced golfers performed 55 golf swings each. In addition to the recordings of the motion capture system a commercially available radar device (Swingmate, Beltronics Inc.) was used to determine the clubhead velocity at impact. A board with two vertical rows of photo sensors was placed next to the player in order to measure the velocity and the launch angle of the ball.

Table 1: Golf swing characteristics, resulting problems and possible solutions:

	Golf Swing Characteristics	*Resulting Problems for 3D Motion Analysis*	*Possible Solution*
(a)	Complex full-body motion	Occlusion of markers	Using a multiple camera system
(b)	Accelerating the club to high velocities is crucial	High velocities of hands, club, and ball	Capturing the motion with high spatiotemporal resolution
(c)	Rotation of legs and arms about their longitudinal axes play an important role	Body segment rotations need to be determined with high accuracy	Using marker sticks to increase the distance of the marker to the rotation axis
(d)	Energy is transferred to the ball in a very short time	Impact causes vibrations	Attaching markers rigidly to the body
(e)	Both hands are in close proximity when gripping the club	Marker accumulation in hands / wrists area if standard marker sets are used	Reducing number of hands / wrist markers

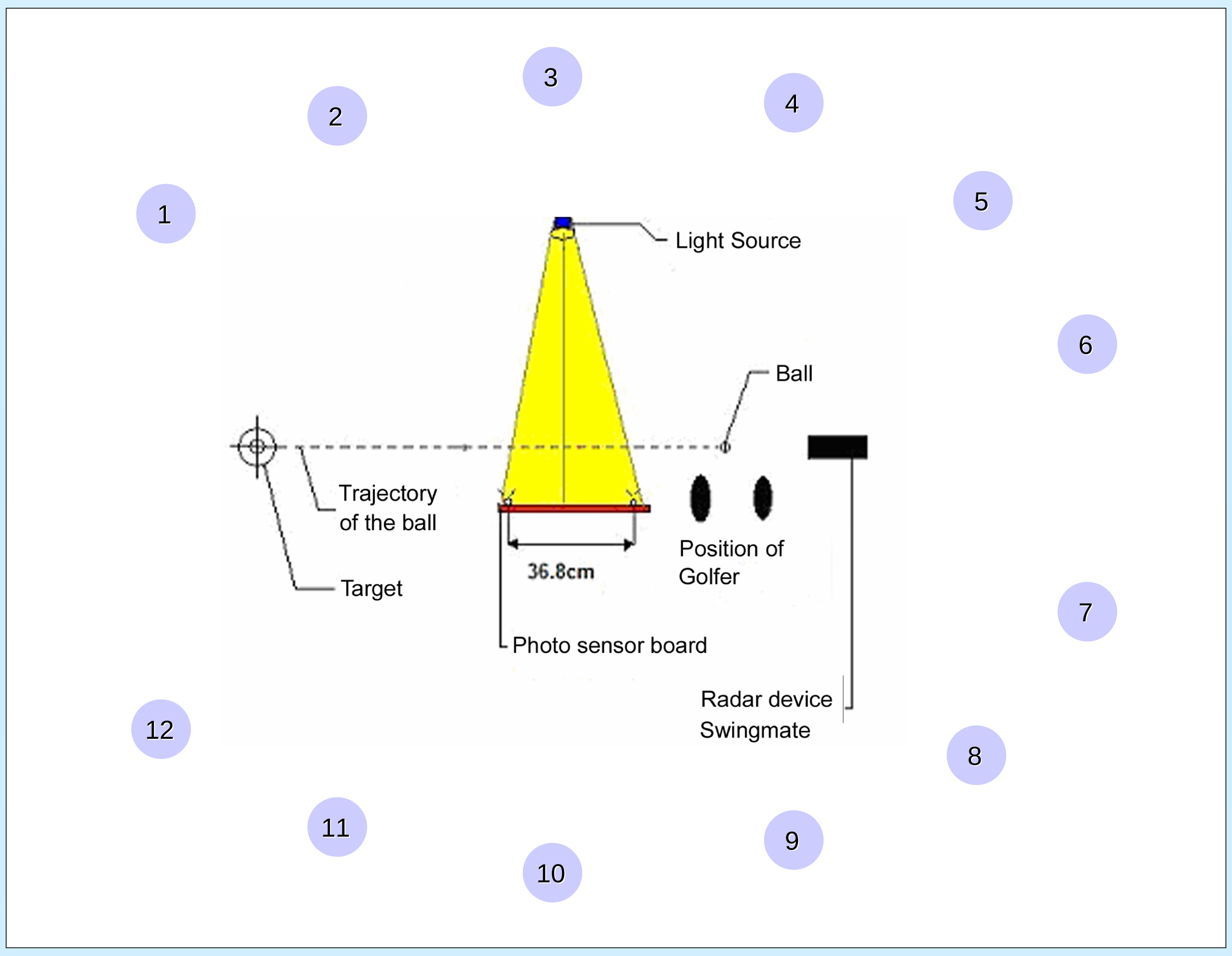

Fig. 1: Test set-up (1-12: Infrared cameras, f=250 Hz)

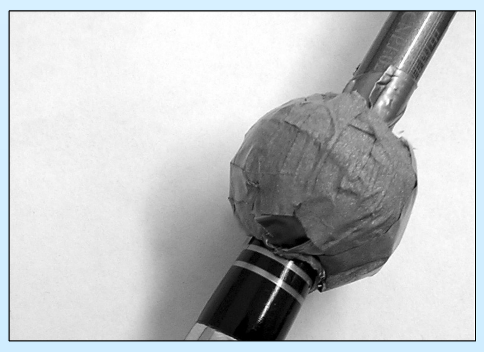

Fig. 2: Club marker

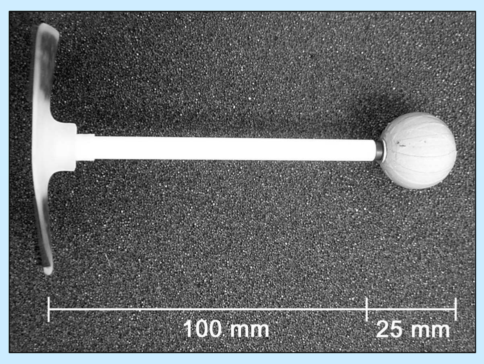

Fig. 3: Wand marker

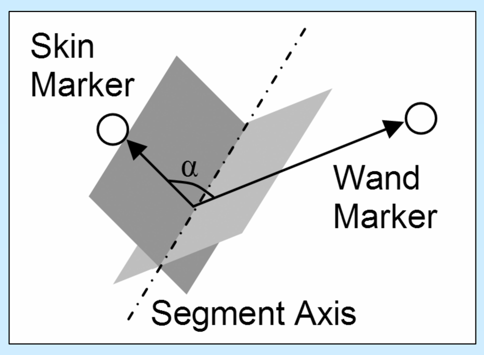

Fig. 4: Definition of wand marker angle

Results and Discussion

Identification and automatic tracking of the modified marker set could be performed more easily due to the reduced number of markers, the modified clubhead marker and the good visibility of the wand markers. However, significant movements of these wand markers relative to the skin occurred, which were similar for all trials (see Fig. 5 for an example). As can be seen from Table 2, significant differences ($p<.05$) between mean clubhead and ball velocities, measured by the 3D motion capture system and the reference devices, were observed. However, a paired comparison of the results from the different devices yielded high correlations.

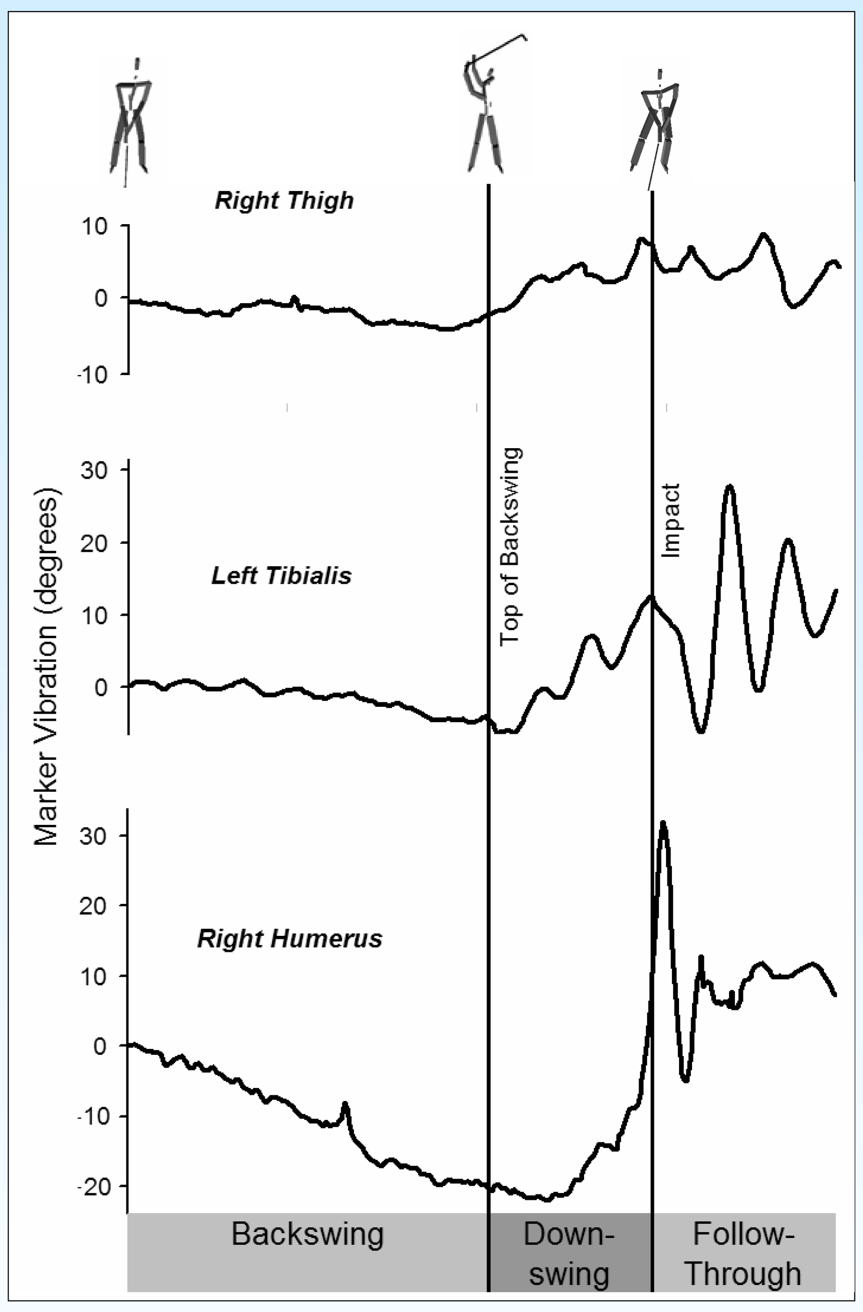

Fig. 5: Example for vibrations of the wand markers (see Fig. 4 for the definition of the angle displayed in the graphs)

Conclusion

In most areas, the golf-specific modifications of the motion analysis procedure yielded improvements. However, the wand markers used were insufficient and either need to be constructed in a different way to become more resistant to vibrations or need to be replaced by skin markers.

A comparison of swing parameters recorded by the 3D motion capture system and two reference systems (Tab. 2) showed significant differences between the results from the different systems. However, correlation of the data sets were high, indicating that systematic errors caused these differences. This confirms that measurements obtained by one system can be compared to other measurements from the same system. If measurements from different systems are to be compared, however, the offset between the values from each system have to be taken into consideration.

Table 2: Comparison of 3D motion capture results with results from reference measurements

Parameter	Number of swings compared	Mean 3D motion capture	Mean reference device	Correlation Coefficient
Clubhead Vel.[a]	106	42.3 m/s	47.6 m/s	0.72
Ball Velocity[b]	71	63 m/s	65 m/s	0.63
Launch Angle[b]	74	14.1°	12.6°	0.94

a Reference device: Swimgmate Radar, b Reference device: Photosensor Board

References

Burden, A.M. et al. (1998): Hip and shoulder rotations during the downswing of sub-10 handicap players. *Journal of Sports Sciences 16*, 165-176.

BRG (2005). *Manual LifeMOD Biomechanics Modeler*. Retrieved on 13th April 2006 from http://www.lifemodeler.com