ANALYSIS OF LEFT ARM SEGMENTAL CONTRIBUTION IN GOLF SWING

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The object of this study is to examine the segmental movement of the left arm in a golf swing and determine its contribution to the final club head speed. In order to examine this movement, a procedure for quantifying joint movement was developed. Electrogoniometers (Biometrics, UK) with frequency of 1000 Hz were attached to the subjects during the execution of the swing to obtain the joint angles throughout the motion. The velocities of the segment rotation can be computed with dual velocity analysis. A zero handicapper was tested with the method. The method uncovers the importance of longitudinal segmental rotations in his swing. These rotations are often neglected in 2-dimensional approaches.

KEY WORDS: arm segment rotation; golf swing; goniometer; dual euler angle; dual velocity.

INTRODUCTION: Most golfers tend to associate the improvement of their games with the improvement of their golf swing. The knowledge of how one uses the different segmental motion to strike the ball may provide valuable information. Several authors (Budney and Bellow, 1982), (Cochran and Stobbs, 1968), (Jorgensen, 1970) and (Lampsa, 1975) have studied the golf swing taking the two-link flail as the basis for a system analysis. However, modeling golf swing as two-dimensional action may be a little simplistic to provide useful feedback to enhance performance. The objective of this study is to examine the time history of the segmental movement of the left arm in a golf swing. In order to examine this movement a procedure for quantifying the segmental movement was developed. With this procedure, the contribution of the quantified segmental rotations to the club head speed of a golf swing can also be ascertained.

METHOD: The method involved utilizing electrogoniometer (biometrics, UK) to obtain the joint angles of the left arm throughout the motion. The time history of shoulder (anteversion/ retroversion; external/internal rotation; abduction/adduction), elbow (flexion/extension), forearm (pronation/supination), wrist (flexion/extension; radial/ulnar abduction) movement can be recorded using the goniometers. The data sampling frequency of the EGMs was set at the maximum of 1000Hz. The data were cleaned with Savitzky-Golay smoothing filter, with 99 points and order of 8, using a standard routine in Matlab (The Math Works, Inc., Natick, USA). The golf swing in this study was depicted as a five segment model. The procedure for computing the segmental rotation consisted of attaching an orthogonal Cartesian frame to each segments. The coordinate system {1} was attached to the trunk at the glenohumeral joint, {2} was attached to the upper arm at the elbow joint, {3} was attached to the hand at the wrist joint, {4} was attached to the end of the grip as the club shaft coordinate system and {5} was attached to the center of the club head as the clubhead coordinate system (Figure 1). The directions of the three axes of each frame were constructed so as to approximate the different axes of rotation for each segment and the origin was located at the center of each relevant joint. The constructed orthogonal axes for the three arm segments were assumed to represent their anatomical axes. The following assumptions are made for the study: The valgus/varus rotation at the elbow joint was assumed as zero.

The longitudinal rotation of the hand at the wrist joint was also assumed to be zero. The shaft and clubhead of the golf club were assumed to be rigid bodies.

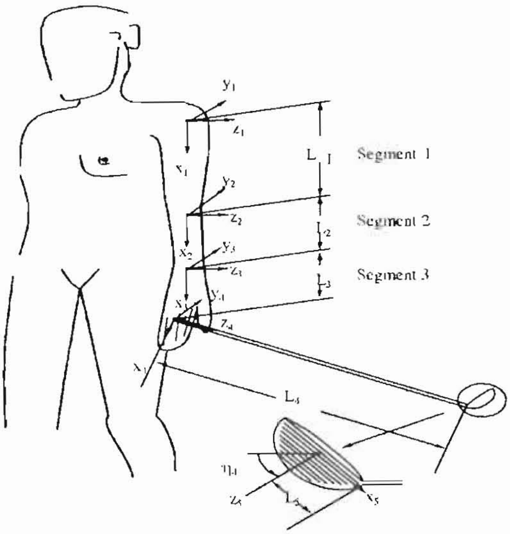

Figure 1: The anatomical position and positions of frames on the subject and the club head.

In order to quantify the joint motions of the swing, the dual Euler angles method (Ying and W.Kim, 2002), based on dual number method (Fischer, 1999), was used. Similar to the Euler angles method, the ordered sequence of screw motion in dual Euler angle method must also be adhered. Therefore, the screw motion sequence Zy'x" was observed in this study.
Considering the Denavit-Hartenberg parameters (Denavit and Hartenberg, 1995) the individual joint-link transformation matrices based on dual Euler angle were:

$$_{n+1}M = Z(\gamma_n)\,y'(\beta_n)\,x''(\alpha_n)$$

Each of the joints was simulated to be driven by a motor that produce the angular rotations equivalent to contractions of spanning muscles. Therefore the velocities at the shoulder, elbow and wrist joints can be represented respectively by

$$^{1}\hat{V}^{1}_{10} = \begin{Bmatrix} 0+\varepsilon\dot{x}_1 \\ \dot{\beta}_1+\varepsilon\dot{y}_1 \\ \dot{\gamma}_1+\varepsilon\dot{z}_1 \end{Bmatrix} \qquad ^{2}\hat{V}^{2}_{21} = \begin{Bmatrix} \dot{\alpha}_1 \\ 0 \\ \dot{\gamma}_2 \end{Bmatrix} \qquad ^{3}\hat{V}^{3}_{32} = \begin{Bmatrix} \dot{\alpha}_2 \\ \dot{\beta}_3 \\ \dot{\gamma}_3 \end{Bmatrix}$$

where $^{R}\hat{V}^{P}_{ij}$ =dual velocity at a point P of body i relative to body j in terms of the unit vectors of frame {R}.
The dual velocity of the end point (i.e. the point on the center of the club head) is given by the contribution of each motor such that:

$${}^5\hat{V}^5_{30} = {}^5_3\hat{M}({}^3\hat{V}^3_{10} + {}^3\hat{V}^3_{21} + {}^3\hat{V}^3_{32})$$

$$= {}^5_3\hat{M}\,{}^3_2\hat{M}\,{}^2_1\hat{M}\,{}^1\hat{V}^1_{10} + {}^5_3\hat{M}\,{}^3_2\hat{M}\,{}^2\hat{V}^2_{21} + {}^5_3\hat{M}\,{}^3\hat{V}^3_{32}$$

The forward velocity of the club head can be defined as the y-component of the dual component of $\hat{V}$ whose direction is always normal to the club head (Figure 1).

RESULTS & DISCUSSIONS: To test the algorithm, calculated velocity of the club head is compared to the measured velocity of the club head. The calculated velocity is derived using the algorithm while the measured velocity is derived using the Video Analysis (Peak Technology, 200Hz). The closeness of the 2 curves in Figure 2 indicates the workability of the proposed method.

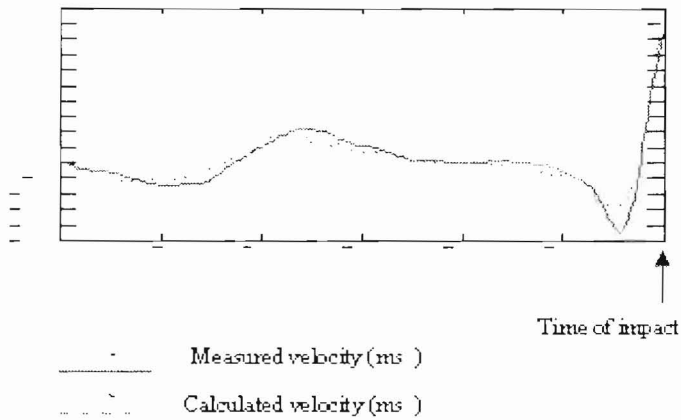

Figure 2: Comparison between the calculated and measured club head velocity.

Table 1 shows the individual contributions of the different segment to the final forward velocity. For this particular golfer, the forearm supination, upper arm external rotation and hand extension contributed significantly (more than 60%) to the final club head velocity. The contribution of the hand extension together with ulnar deviation, commonly known as the hand "cocking" movement, shows good agreement with many simulations and experiments done by Sprigings and Neal (2000) This study reinforce the importance of wrist "uncocking" in achieving a high club head speed. This study also uncovers the importance of external rotation of upper arm and supination of the forearm in golf swing. These two rotations along the longitudinal axes are neglected with use of the traditional 2-dimensional approaches. Details of such joint actions were detected with the present three-dimensional segmental analysis. The results also indicated that some arm rotations contributed insignificantly to the final velocity hence their function might be to put other segments in the position for performing a rapid swing.

Table 1 Individual contribution to the forward velocity at the impact.

	Resultant club-head velocity	Upper arm: retroversion+ / anteversion–	Upper arm: adduction + / abduction–	Upper arm: internal + / external rotation–	Forearm: extension+/ flexion-	Forearm: pronation+ / supination–	Hand: extension + / flexion –	Hand: ulnar +/ radial abduction-
Angular velocity (Rad/sec)	38.827	-1.1	-4.028	-9.57	4.203	-8.153	12.002	4.893
Individual Linear velocity (m/sec) (%)	28.923 (100%)	0.868 (3 %)	3.86 (13.35%)	7.35 (25.41%)	0.912 (3.15%)	6.12 (21.16%)	9.813 (33.93%)	0 (0%)

CONCLUSION: The procedure introduced in this study could provide useful information of the segmental movement of the left arm for golf swing. The quantification of movements and their velocities as in the present study will assist coaches/athletes to improve their perceptions of technique differences. This method of characterizing the swing can enable golfers to compare their golf swings to that of the more proficient ones. Golfers can then understand his own swing better and identify his strengths and weaknesses. As the arm has seven degrees of freedom, focusing on the few important actions will simplify the swing coordination and accelerate the learning process. The use of electrogoniometers also provides many advantages. The fact that the electrogoniometers used in the study sample signals at 1000Hz would eliminate some aliasing errors compared with the used of video analysis (200Hz). Data extraction from electrogoniometers can be made available almost immediately without much processing. The consideration of digitizing errors in video analyses can be eliminated with the use of electrogoniometer.

The method provides an efficient approach of assessing the effectiveness of the arm segment rotations in producing club head speed. This method can be easily applied to other sports to describe and assess the contribution of segmental rotations to performance. In general, the method provides convenient approach to record and analyze movement and most importantly it provides detailed information which may otherwise be omitted with other approaches.

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