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BIOMEHANICAL MODEL OF THE GOLF SWING TECHNIQUE

Introduction

Performance in golf depends on numerous factors, among which the key importance is undoubtedly attributed to those defining the technique of stroke. In the history of golf, the study of the secrets of this element was constantly present in the play of numerous amateurs as well as professionals. Many books and manuals, written as a rule by grand masters of the golf game, were dedicated to this "cult event" (Allen, 1992).

Completely new possibilities in the field of studying the stroke technique have opened up by modern video technique used in conjunction with computer technology. By means of special software tools we can establish the most important quantitative biomechanical parameters of the stroke in a three-dimensional space (Simeon, Coleman, Rankin, 2005). In the present study, we use the method of kinematic analysis that ensures accurate recording and evaluation of the most important parameters of the stroke such as paths - trajectories, the values of angles, speeds, angular speeds and accelerations for individual parts or segments of the body, and the parameters of the movement of the club and ball. The mentioned data are obtained by transferring video images into the computer, using the procedure of digitalisation of a 15-segment model of the golf player. Since we have the player's data in a three-dimensional space, we can study the player in any phase of the stroke crucial for the technique.

On the basis of the available literature, we find that in the course of the development of the golf game, the technique of strokes changed markedly (Hay, 1985; Allen, 1992; Owens, 1992). Today there still exist large individual differences in the stroke technique between the best professional players, which fact is not surprising since we know that the said differences are the result of the differences in their motor abilities and anthropometric characteristics. The stroke in golf, or more precisely, its accuracy, directly affects the playing result, therefore it is not surprising that the search for new approaches and methods to improve this element of the play is always equally topical and present in the training process. A high degree of the standardisation of movement, co-ordination in time and space (timing), the control of the movement of the player-club-ball system are those key factors that in interaction generate the successfulness of a stroke and thereby to a large extent also the playing performance (Wiren, 1997; Simeon, Coleman, Rankin, 2005).

In view of the fact that the quality of a stroke in golf is one of the most important factors, the object of the study was to identify some most important quantitative kinematic parameters in two different strokes - namely, a stroke with a wood and with an iron - and to establish the differences between the players and the differences arising from the use of the two different types of clubs.

Methods

The study is as a result of the co-operation between the Professional Golf Association of Slovenia and the Laboratory for Biomechanical Measurements at the Faculty of Sport of Ljubljana. Measured were three Slovene professional golfers (M.L., D.J., and J.G) each of whom performed three strokes with two different clubs (wood, iron). To establish kinematic parameters, a 3-D video system for kinematic analysis called APAS (Ariel Performance Analysis System) and CMAS (Consport Motion Analysis System) were used. The stroke technique was filmed with two High-Speed cameras (JVC TK 1281) placed perpendicular to each other. The cameras were image-synchronised. The cameras were placed in front of the golfer at an angle of 45° and 135°, respectively, to the direction of the stroke. The frequency of shots was 2000 Hz. The masses and centres of gravity of the segments and the common centre of gravity of the golfer's body were calculated according to the anthropometric model (Dempster, 1955). All kinematic parameters were filtered with a Butterworth filter of 7^{th} degree. The space was calibrated with a reference cube and defined with the horizontal X-axis, vertical Y-axis, and transversal Z-axis. The criterion for the selection of the stroke for analysis was the launch speed of the ball.

Results and discussion

The results of the kinematic analysis of the stroke with a wood and the stroke with an iron point to it that in this respect there also exist large individual differences between the golfers in the sample selected. The strokes differ both in the speed of individual body segments, the speed of the club, and the speed of the ball at the moment of impact. Considerable differences can also be established in the trajectory of the clubhead tip in all phases of the stroke**.** From figure 1 it is possible to establish the values of the speed of the ball, the speed of the clubhead tip, and the speed of the right wrist at impact.

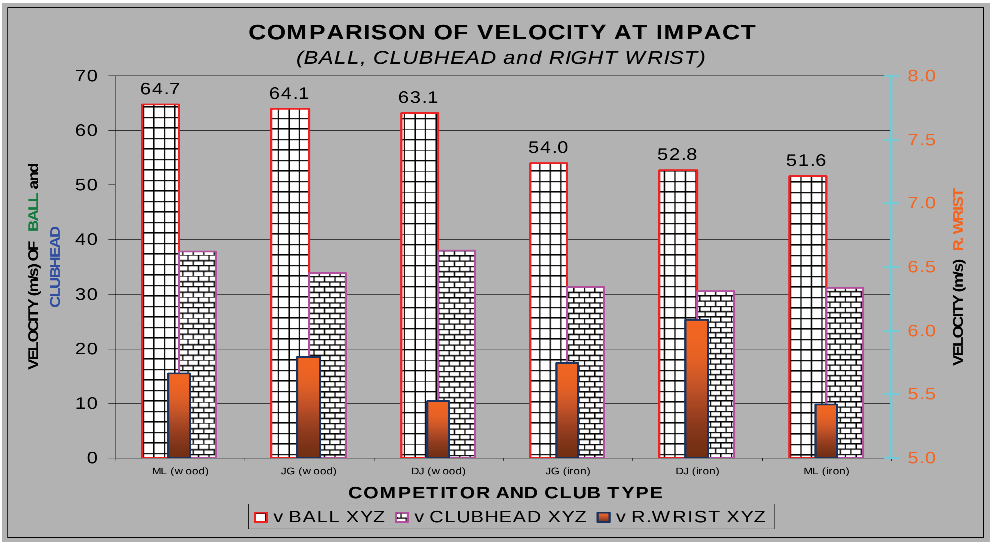

Figure 1. *Speed of the ball, speed of the clubhead tip, and speed of the right wrist at impact in the stroke with a wood and an iron, respectively*

The highest speed of the ball in the stroke with a wood was attained by M.L., 64.7 m/s (233 km/h), the next was J.G. who reached the speed of 64.1 m/s (230 km/h), and the lowest speed, 63.1 m/s (227 km/h) was achieved by D.J. The average speed is 63.9 m/s (231 km/h). The speeds of the balls when performing the stroke with an iron were on average by 10 m/s smaller in all three golfers. From figure 4 it can also be concluded that the contribution of the speed of the clubhead tip and the right wrist to the launch speed of the ball can vary considerably. The speed of the ball is not necessarily the highest in the player who achieves the highest speed of the clubhead tip at impact because the stroke can be performed eccentrically and hence a part of the speed of the club is utilised for the rotation of the ball.

Figure 2 shows the principles of the changing of the speed of the clubhead tip and the right wrist as a function of time in three key phases of the stroke. The speed of the clubhead tip increases gradually up to the last third of the backswing and than decreases down to the value 0 due to the change of the direction of movement into the downswing phase. In the downswing phase there occurs a steep increase in speed up to its maximal value just before the point of impact.

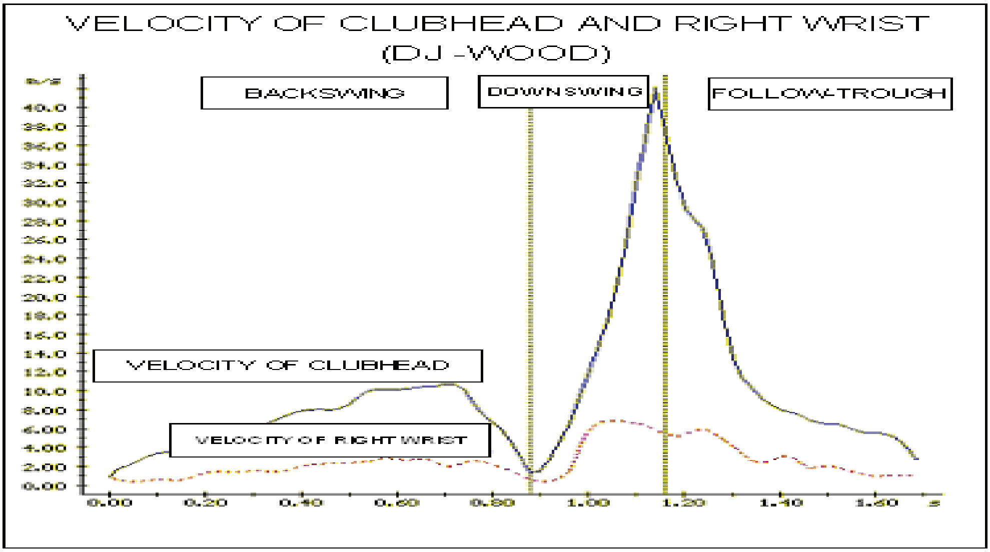

Figure 2. *Speed of the clubhead tip and the right wrist as a function of time for a wood.*

The speed decreases gradually until it stops in the finish of the stroke. A very similar tendency of speed changing has also the right wrist, its speed being on average by 6.5 times smaller than that of the clubhead tip. The average maximal speed of the clubhead tip in the golfers of our sample is 36.6 m/s (132 km/h). The largest speed of the clubhead tip attained D.J., 41.9 m/s (151 km/h). However, the results obtained must be to a certain extent taken into account with a reservation since the technology available to us for carrying out these measurements has certain limitations. The main limitation is a relatively low frequency (50 Hz) of the used cameras. For absolutely correct studying of the issues of this kind, special video cameras with a frequency of 500 or more frames per second were necessary.

The angular parameters in the position at the top of the backswing (the begin of the downswing) and impact provide some essential information on the quality of the stroke. The largest differences between golfers occur in the angle between the hip axis and the direction of the stroke at the moment of impact. J.G. has the largest angle at this point, namely 45°. As regards other angles, there are no significant differences between the golfers. The average value of the angle of the shoulder axis relative to the direction of stroke at the top of the backswing amounts to 104.9°, here the largest angle is attained by D.J., namely 109.3°; the angle attained by J.G. is 105.4°; and the angle attained by M.L., 100° (a larger angle means a stronger “winding” and “thereby a stronger possibility of the utilisation of the elasticity of the trunk rotators). In the impact phase, the angle between the shoulder axis and the direction of the stroke amounts on average to 13°; here, the largest angle is achieved by J.G., namely 17°. At the top of the backswing, the average angle between the shoulder axis and the hip axis is 73° in all three golfers. The most pronounced “winding” of the trunk has thus D.J., namely 76°, then follows J.G with 72°, and M.L. with 71°.

On the basis of the changing of the angles between the various segments of the body and the angle of the vector of the velocity of the clubhead tip (Figure 3) we can establish the entire complexity of the time and spatial synchronisation (timing) in performing the stroke.

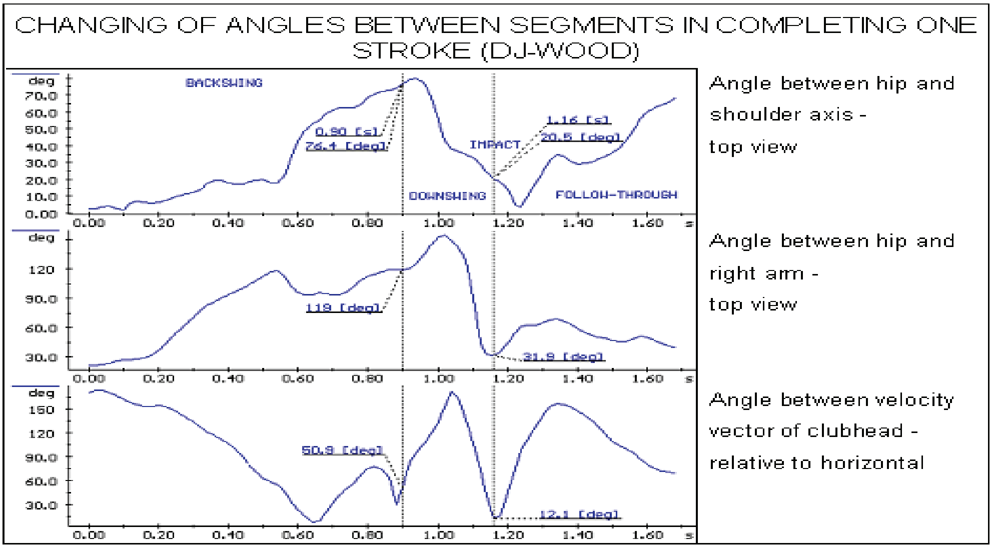

Figure 3. *Angle between the hip axis and shoulder axis, angle between the shoulder axis and the arm, and angle of the vector of the speed of the clubhead tip relative to the horizontal (X-axis). The first vertical line designates the position of the top of the backswing (end of backswing), and the second one the position of impact.*

In the beginning of the stroke, the shoulder and hip axis are almost parallel, then the angle between them gradually increases until it reaches the half of the backswing phase. In the second half of the backswing, the angle increases rapidly, and begins to fall off steeply in the beginning of the downswing, which is the result of the “unwinding” of the trunk rotators. The angle between the shoulder axis and the arm in the downswing phase indicates that eccentric-concentric muscular strain occurs.

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SUMMARY

Golf is an extremely complex game which depends on a number of interconnected factors. One of the most important elements is undoubtedly the golf swing technique. High performance of the golf swing technique is generated by: the level of motor abilities, high degree of movement control, the level of movement structure stabilisation, morphological characteristics, inter- and intro-muscular co-ordination, motivation, and concentration. The golf swing technique was investigated using the biomechanical analysis method. Kinematic parameters were registered using two synchronised high-speed cameras at a frequency of 2,000 Hz. The sample of subjects consisted of three professional golf players. The study results showed a relatively high variability of the swing technique. The maximum velocity of the ball after a wood swing ranged from 233 to 227 km/h. The velocity of the ball after an iron swing was lower by 10 km/h on average. The elevation angle of the ball ranged from 11.7 to 15.3 degrees. In the final phase of the golf swing, i.e. downswing, the trunk rotators play the key role.

Key words: *golf, technique, kinematics, velocity parameters*