

BIOMECHANICAL GOLF SWING ANALYSIS

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The Biomechanics Laboratory of the Australian Institute of Sport has spent eight years developing a comprehensive golf swing analysis system. The system is designed to assist the golfer and professional golf coach in identifying problems within the golfer's swing to enable corrections to be made so that the golfer may reach full potential. Correct weight transference is a major component of the perfect swing. The Golf Analysis System measures changes in the centre of pressure of the golfer during the swing which provides a measure of the golfer's weight transference pattern. The path of the centre of pressure is plotted out in relation to the position of the feet and the ball. The centre of pressure path is divided by colour coding into the three major phases of the swing: TAKE-AWAY, DOWNSWING & FOLLOW-THROUGH. The timing for each phase is obtained from the split screen video image of the swing from time information encoded on the video picture. The instant of ball impact is combined with this and is recorded by a microphone located immediately beneath the ball. The centre of pressure within each foot is also plotted out in a similar fashion to the centre of pressure of the entire golfer.

The path the club follows during the swing is directly related to the quality of the swing. An automatic digitising system is used in the Golf Analysis System to capture the location of the club shaft every one two-hundredths of a second during the swing. This path is then reconstructed by computer, plotted on paper and animated on video for review purposes. Views from the front, side and above of the club path plane are reconstructed in relation to the movement of the leading shoulder for examination.

The absolute velocity of the club's head is obtained and plotted out from 0.1 sec. before impact to 0.1 seconds after impact. The velocity components of the club head in the forward, crossways (swing path) and vertical (attack angle) direction are also plotted out which provides information as to the direction the club head is moving at the time of ball contact. A graph of the angle that the club is making to the desired ball path is also graphed out from 0.02 seconds before impact to 0.02 seconds after impact.

A split vision video image of the golf swing is filmed during the swing. This is captured by way of two shuttered S-VHS video cameras located directly above and to the open side of the golfer. The video provides a complete visual image of each entire golf swing analysed.

The position of the golf club head during ball contact phase has a direct relationship to the path the ball will follow after ball contact. In the Golf Analysis

System the path of the golf club head is captured by a high speed video camera (400 frames per second) several frames before ball contact to several frames after contact. This information is provided in the form of four sequence photos. Information is therefore obtained about where ball impact occurred on the club head. Any misalignment of the head during the contact phase together with any resulting twisting of the club's head as a consequence of a non-centred impact is also identified. To identify the angle the club head face is making to the desired ball path direction, up to eight images from the high speed video are digitised and the resulting information is output in a diagrammatic format.

Research in the USA has identified the angle between the club shaft and the leading forearm is linked to the club head velocity at impact. It was found that the duration that this angle is kept below 90 degrees, prior to ball contact within the downward swing, is positively correlated to the club head velocity at contact. Graphical output provides information associated with the angle between the club shaft and the leading forearm during the downswing. As well as this the two dimensional angle in the vertical plane, as seen from a position looking towards the front of the golfer at right angles to the hitting direction, and the three dimensional angle of both the club shaft and the leading forearm to the ground are plotted throughout the contact phase. This provides information as to the leading forearm and club shaft movement planes and the relationship between the two just prior to the contact phase. The forward velocity of the golfer's wrist is also graphed near ball contact.

Sensors in the tee-off platform provide immediate feedback on the velocity of the club head immediately before impact and velocity of the ball immediately after impact. The direction and elevation of ball flight is also measured by sensors. A print out of this information together with where the ball would have landed as a result of the swing is also provided in printouts.

The Golf Analysis System provides valuable information about the golfer's swing which if used properly can produce drastic improvement in the golfer's game. To be most effective a professional golf coach should be utilised to eliminate faults which are disclosed by the Golf Analysis System.

In September of 1994, the A.I.S. Biomechanics Laboratory analysed the swings of 64 P.G.A. third year apprentices. These subjects represented a homogeneous group of low handicap golfers. The third year apprentices were instructed during their performance to hit their normal driver shots. They were given no indication that they should attempt to reach a high club head speed. A statistical analysis was performed on information derived from the resulting package which was supplied for the apprentices. The research was performed to gain insight as to factors in the swing which may influence club head velocity. The two variables used as criteria variables were Club Head Velocity in the Forward Direction at Impact ($m=156\text{kph}$ $n=57$) and Maximum Forward Velocity

of the Club Head ($m=163\text{kph}$ $n=57$). In total 37 variables were correlated with the two criteria variables listed above. To avoid discarding any variables which may possibly be related to attaining club head forward velocity a significance level of 0.05 was used. Variables that were significantly correlated with Maximum Forward Club head Velocity were: Time Before Impact when the Club shaft appeared Vertical above the golfer's head ($m=-0.089\text{sec}$, $r=0.66$ $p<0.0001$ $n=53$), Time Before Impact when the Club shaft appeared Horizontal ($m=-0.040\text{sec}$, $r=0.56$ $p<0.0001$ $n=55$), Time After Impact when the Club shaft appeared Horizontal ($m=0.063\text{sec}$, $r=-0.49$ $p<0.0002$ $n=54$), Angle of the Club shaft from a Vertical Alignment when it appears to be perpendicular to the ground ($m=40\text{deg}$, $r=-0.30$ $p<0.026$ $n=55$), Position of the Centre of Pressure on the Left Foot at ball impact as a percentage of foot length from the heel ($m=57\%$, $r=0.28$ $p<0.036$ $n=57$), Time before Contact when Maximum forward Velocity Occurred ($m=-0.003\text{sec}$, $r=0.25$ $p<0.056$ $n=57$), Position of the Centre of Pressure on the Right Foot at the commencement of the Downswing as a percentage of foot length from the heel ($m=54\%$, $r=0.25$ $p<0.059$ $n=57$). Variables that were significantly correlated with Club head Velocity in the Forward Direction at Impact were: Time Before Impact when the Club shaft appeared Vertical above the golfer's head ($m=-0.089\text{sec}$, $r=0.58$ $p<0.0001$ $n=53$), Time Before Impact when the Club shaft appeared Horizontal ($m=-0.040\text{sec}$, $r=0.54$ $p<0.0001$ $n=55$), Time After Impact when the Club shaft appeared Horizontal ($m=0.063\text{sec}$, $r=-0.39$ $p<0.003$ $n=54$), Time before Impact when Maximum forward Velocity Occurred ($m=-0.003\text{sec}$, $r=0.50$ $p<0.0001$ $n=57$), Position of the Centre of Pressure on the Left Foot at the commencement of Takeaway as a percentage of foot length from the heel ($m=55\%$, $r=0.30$ $p<0.023$ $n=57$), Swing path Velocity at Impact ($m=8.2\text{kph}$ {outwards}, $r=0.30$ $p<0.026$ $n=57$), Attack Velocity at Impact ($m=-3.7\text{kph}$ {downwards}, $r=-0.28$ $p<0.037$ $n=57$), Club head Attack Angle at Impact ($m=-1.2\text{deg}$ {downwards}, $r=-0.26$ $p<0.049$ $n=57$) and Club head Swing path Angle at Impact ($m=3.0\text{deg}$ {out}, $r=0.25$ $p<0.056$ $n=57$). The time until impact when the 3D wrist angle increased beyond 90deg {uncocking of the wrist} ($m=-0.067\text{sec}$, $r=0.21$ $p<0.188$ $n=41$) was not significantly correlated with either criteria variable.

In summary, a number of variables correlated significantly with the criteria variables representing club head speed. Some of these variables are related for obvious physical reasons to club head speed. It was interesting to note the relationship of club head speed to the position of the center of pressure in the left foot at Takeaway and at Impact. These variables are probably related to dynamic balance of body weight along the line of the frontal plane during the swing. Another variable of note was the alignment of the club shaft as it appeared to move through the vertical position near impact. Here the negative correlation implied that as the club shaft alignment reduced (club shaft became more vertical)

then the velocity of the club head increased. It was also noted that on average the club head was moving in a downward, outward direction at impact. The research indicated that Maximum club head speed was obtained on average 0.0032sec prior to impact. The highly significant correlation between Club head Velocity at Impact and the Time before Impact that the club head was at its maximum velocity, suggests that greater club head speed at impact can be obtained if this period of time is **minimised**. Whether this implies the maximum velocity should coincide with impact is uncertain. Prior research that indicated a delay in the **uncocking** of the wrists tended to increase club head speed was not supported by this study.