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Hub Movement During the Swing of Elite and Novice Golfers

Ross H. Sanders and Peter C. Owens

Many golf coaches refer to a focal point or "hub" of a golf swing and encourage players to imagine the clubhead rotating about this point. The purpose of this study was to locate the hub of the swings of elite (handicaps 0–5) and novice golfers. Six novice and six elite players (all male) each performed 10 swings with the 3-wood provided. Motions of reflective markers attached to the vertex and chin of the subject and three points along the shaft of the club were recorded on videotape. The position of the hub at sampled instants during the swing was defined by the intersection of normals to the clubhead path. Among elite players the hub was not fixed and the pattern of hub movement was consistent. The radius of the hub to the clubhead reached a maximum near impact. Novice players tended to achieve maximum radius after impact and the hub patterns were inconsistent.

When instructing players to establish a consistent swing, many coaches use the concept that the swing has a center or "hub" (Leadbetter, 1990). The location of the hub is of interest for two main reasons. First, it may differentiate between good and poor technique. Second, a mental image of the position of the hub may assist in developing a technically sound swing (Cochran & Stobbs, 1968). However, there has been no clear consensus with regard to what the hub actually represents or where it is located during the swings of elite players.

Several authors describe the swing in terms of rotations about particular axes that have some anatomical significance. Cochran and Stobbs regarded the hub as a fixed center for the rotation of the upper lever (arms). Wiren (1990) referred to a central pivot or "swing center" as a point located near the top of the spine around which the upper body rotation and swing of the arms takes place. Leadbetter (1990) suggested that there may be two axis points during the swing; the clubhead rotates about the right shoulder on the backswing and rotates about the left shoulder during the downswing (for a right-handed player). Others have modeled the swing as a double pendulum with the motion of the club being dependent on the interactive effect of rotations about two axes (Budney & Bellow, 1982; Jorgensen, 1970; Lampsa, 1975; Milburn, 1982; Neal & Wilson, 1985; Williams, 1967).

In this study it was proposed that the hub could be regarded as the focal

The authors are with the School of Physical Education, University of Otago, Dunedin, New Zealand.

point of the path of the clubhead and may be determined simply by finding the intersection of normals to the tangents of the clubhead path. This conceptualization of the hub of the swing does not require that the center of the swing be a point with any particular anatomical significance or that it remain fixed within the body.

The purpose of this study was to describe the movement of the hub (defined as the focal point of the clubhead path) of the golf swing in the plane of motion of the clubhead and to compare these paths across elite and novice players.

Method

Experimental Procedure

Six novice (played less than once a year) and six elite (current handicap ranging from 0 to 5) male right-handed golfers participated in the study. Reflective markers were attached to the vertex of the head and chin, and three markers were placed on the shaft of the club, spaced 35 cm apart, to define the line of the club shaft. The positions of these markers were subsequently used for scaling and calculation of the center of the clubhead. Subjects wore dark clothing to reduce reflection of light back to the video cameras.

The experiment was conducted over 2 days, with novice players being tested on the first day and elite players on the second. Prior to testing, subjects were required to participate in a warm-up routine consisting of stretching exercises and a minimum of 10 practice swings. Each subject then performed 10 swings with the 3-wood provided, standing on a large mat that simulated ideal ground conditions, and hitting a hollow soft rubber practice ball that he positioned for each trial. A drop net stopped the motion of the ball.

Motion of the reflective markers was recorded by a Nac high-speed video camera operating at 200 frames per second with an exposure time (shutter speed) of 1/5000 s. This short exposure time minimized blurring of the reflective markers on the videotape. Sufficient light for such a short exposure time was provided by 6000 watts of focused lighting evenly distributed through the area of the swing. Black curtains provided a background to enhance the contrast of the reflective markers. The camera was 11 m from the subject and perpendicular to the intended direction of the shot. Because each subject's swing plane was not vertical (the swing plane was typically 128° to the horizontal, quantified by digitizing video taken from the side of a typical swing), the camera was positioned 3.5 m above the floor and angled downward to reduce perspective error. Perspective error was further reduced during scaling procedures.

Analysis

The positions of the reflective markers were digitized by an automatic Motion Analysis digitizing system. These data were then input to a Fortran program that determined position of the clubhead, position of the hub, and distance of hub from clubhead (radius) over the period from commencement of the downswing to follow-through of the club.

Prior to calculating the variables, coordinate locations were expressed with respect to the resting position of the ball and were smoothed with a recursive 2nd-order Butterworth digital filter with a cutoff frequency of 18 Hz. The scale

for the horizontal coordinates was based on the known distance (70 cm) between the upper and lower shaft markers at the sample when the shaft was closest to horizontal during the downswing: $x_{scaled} = x_{raw} \cdot$ known distance between shaft markers/raw distance between shaft markers

The raw distance between shaft markers was determined by applying Pythagoras' theorem, that is, by taking the square root of the sum of the squared difference in the x coordinates and squared difference in the y coordinates of the upper and lower shaft markers. Similarly, the scale used for the vertical coordinates was based on the distance between the shaft markers at the sample when the shaft was closest to vertical at the bottom of the downswing. These procedures reduced errors due to the swing plane not being exactly perpendicular to the camera axis.

The position of the clubhead was assumed to be in line with the bottom of the shaft, which was determined by extrapolating along the line of the shaft 11 cm from the third shaft marker. Although the center of the clubhead was slightly anterior to the shaft, the results were not affected by this assumption. The position of the hub of the ith sample was defined as the intersection of the ith +1 and ith −1 normals to the clubhead path. These intersections were found as follows:

The position of the head of the club was obtained by extrapolating along the line of the shaft. The slope of the tangent (m) to the curved clubhead path was found using the relationship

$$m_i = (y_{i+1} - y_{i-1})/(x_{i+1} - x_{i-1}).$$

The slope of the normal at the ith point was then $-1/m_i$. The equation of the normal (n_i) at the ith sample point was then

$$y = -1x/m_i + b_i$$

where $b_i = (y_i + x_i)/m_i$. The position of the hub at the ith sample was the intersection of n_{i-1} and n_{i+1} solved by simultaneous equations. Qualitative analysis by observing the videotapes supplemented the quantitative analysis described above.

Results and Discussion

Results for the Elite Players

Figure 1 shows the clubhead path and the hub of an elite player (Figure 1a), an enlarged view of the hub and the path of the vertex and chin (Figure 1b), a further enlarged view of the vertex and chin paths (Figure 1c), and stick figures of the club plotted for every second sample (Figure 1d). An event marker is indicated every 25 ms (five samples) on the clubhead and hub paths in Figures 1a, b, and c. In the case of the vertex and chin, only every second event marker is shown.

The pattern followed by the hub during the swing was typical of the elite players in terms of position and timing, and elite players were very consistent across trials. For example, the standard deviation of the y hub positions at impact (across trials within subjects) was less than 3.6 cm for all subjects. The hub moved forward from just prior to impact (mean = 37 ms prior to impact, *SD* = 3 ms) to shortly after impact (mean = 63 ms after impact, *SD* = 5 ms). During this time the hub moved from a mean position of 8.9 cm behind the ball (*SD* =

5.6 cm) to 28.4 cm (*SD* = 5.2 cm) in front of the resting position of the ball. At impact the mean hub position was 4.9 cm behind the ball (*SD* = 3.9 cm).

The hub moved upward prior to impact, thereby providing a long radius to the clubhead (mean = 139.5 cm, *SD* = 4.8 cm) and a relatively flat path of the club through impact. During this period the hips rotated and the body moved forward over the front foot. A flat path (elevated hub position) through impact would be expected to increase the consistency of the shot because the rate of changing direction of the clubhead was small. Among the elite players the radius was consistently close to its maximum near the time of impact.

At impact the hub was located at a mean of 15.9 cm (*SD* = 2.8 cm) in front of the chin and 17.3 cm (*SD* = 4.3 cm) below the chin. This would place the hub at impact close to the left nipple (for a right-handed player) when viewed from the front and corresponds closely to the axis of rotation defined by Leadbetter (1990), who used the left armpit as an approximation of the hub position at impact.

In contrast to the long radius through impact, the radii prior to impact and after impact were comparatively small (Events 4 to 5 and 8 to 9, respectively, in Figures 1a and 1b). These small radii were associated with rotations about the wrist axis in addition to the shoulder axis. Rotation of the club about the wrists during this period is apparent from the stick figures (Figure 1d). A strong wrist action rotated the shaft to almost vertical at impact, when viewed from a position perpendicular to the swing plane. However, because there was also rapid forward movement of the club due to rotation about the shoulder and lateral movement of the body, the radius approaching impact was long.

Qualitative analysis of the videotapes showed that elite players were characterized by a lateral body movement in the backward direction during backswing and forward through the downswing and follow-through. This was reflected in the lateral movements of the chin marker, and the chin was regarded as a good indicator of lateral body movement. The chin reached its most backward point soon after completion of the backswing (mean = −29.3 cm, *SD* = 8.1 cm), then moved forward during the downswing. However, the chin was still behind the ball at impact (mean = −11.0 cm, *SD* = 3.1 cm). During impact, elite players tended to minimize lateral movement of the vertex and chin (see Figure 1c). During the follow-through, the chin continued to move forward due to forward movement of the body and rotation of the head. At the time that the club reached its highest point in the follow-through, the chin was well forward of the ball's resting position (mean = 19.5 cm, *SD* = 8.0 cm) and the vertex was forward of the ball's resting position (mean 5.6 cm, *SD* = 11.3) for all but one elite player.

Results for the Novice Players

Figure 2 shows the clubhead path and the hub of a novice player (Figure 2a), an enlarged view of the hub and the path of the vertex and chin (Figure 2b), a further enlarged view of the vertex and chin paths (Figure 2c), and stick figures of the club plotted for every second sample (Figure 2d). Because the novice players had much slower swings than the elite players, events are shown every 10 samples (50 ms).

There was great variability in the pattern of hub movement of novice players, both among subjects and among each subject's trials. For example, the standard deviation of the y hub positions at impact (across trials within subjects)

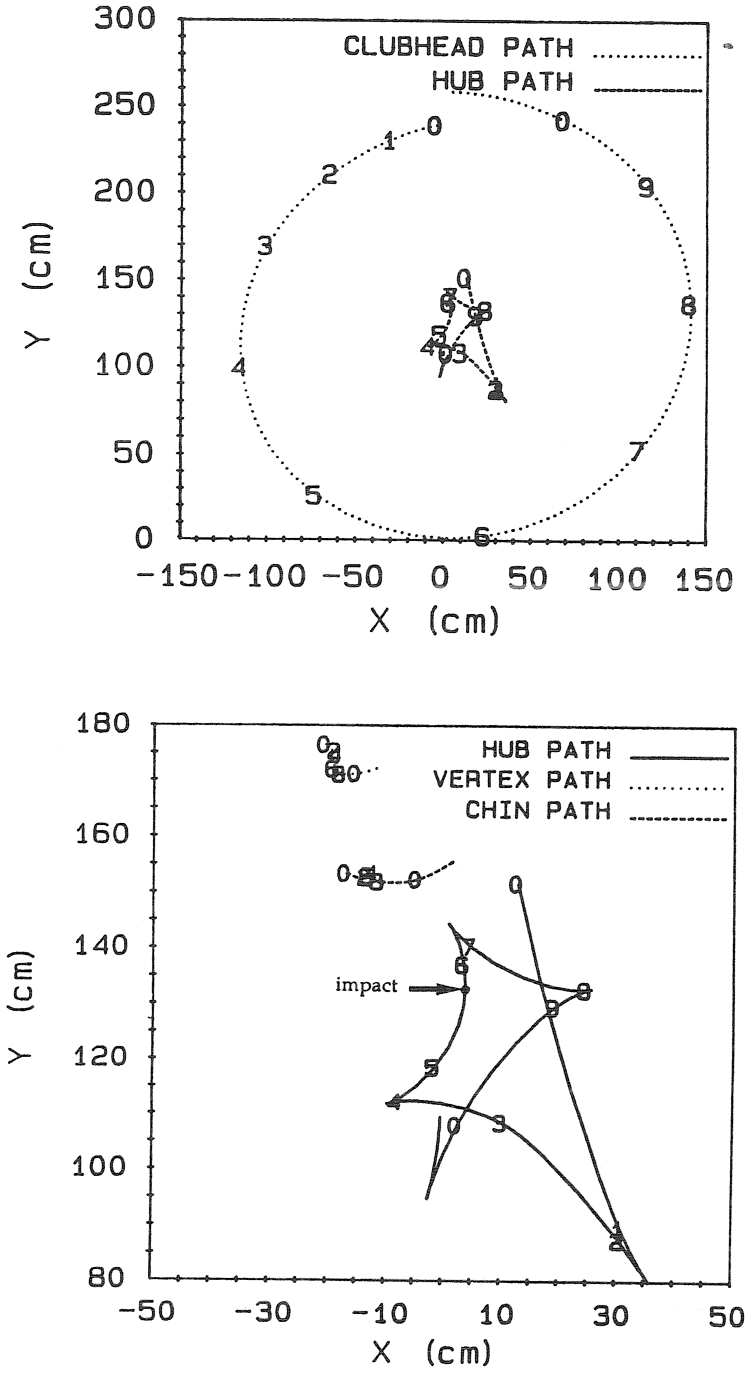
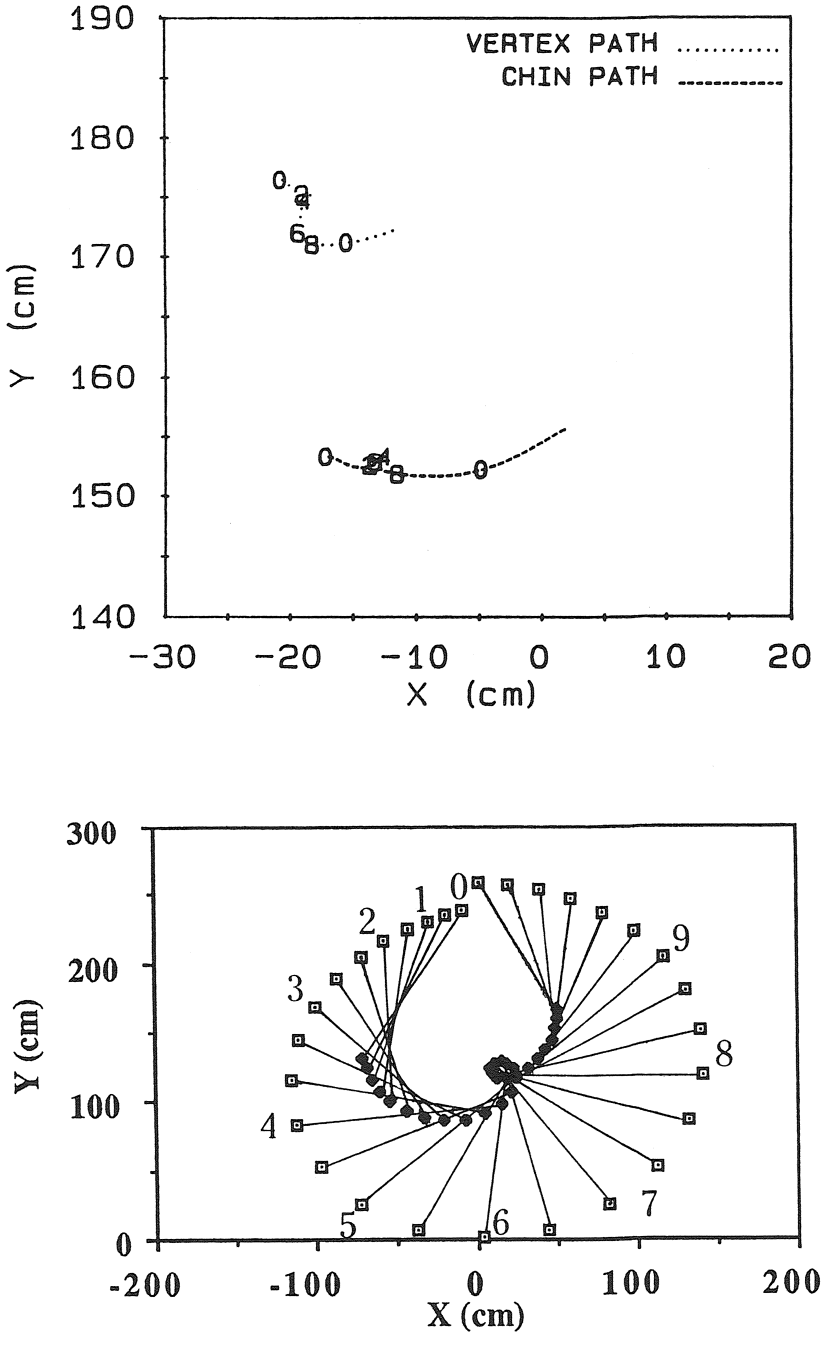


Figure 1 — Clubhead and hub paths (a); hub, vertex, and chin paths (b); vertex and



chin paths (c); and stick figures of the club for every second sample (d) of a typical elite golfer. Sequentially numbered events represent a time interval of 25 ms.

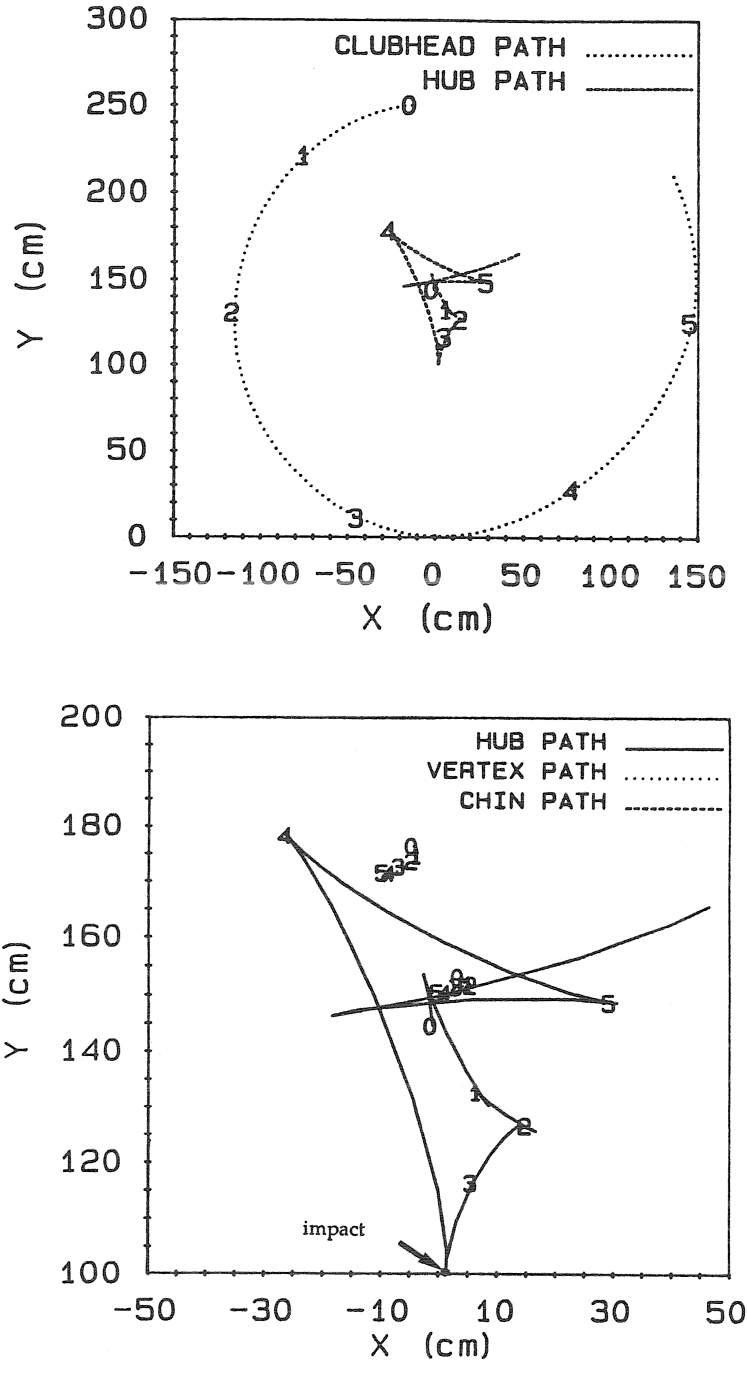
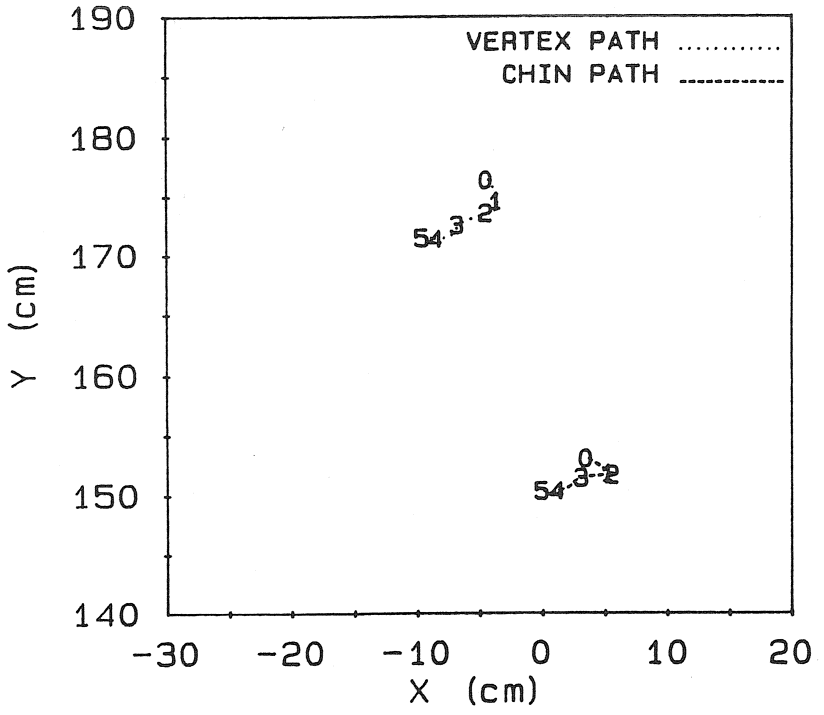
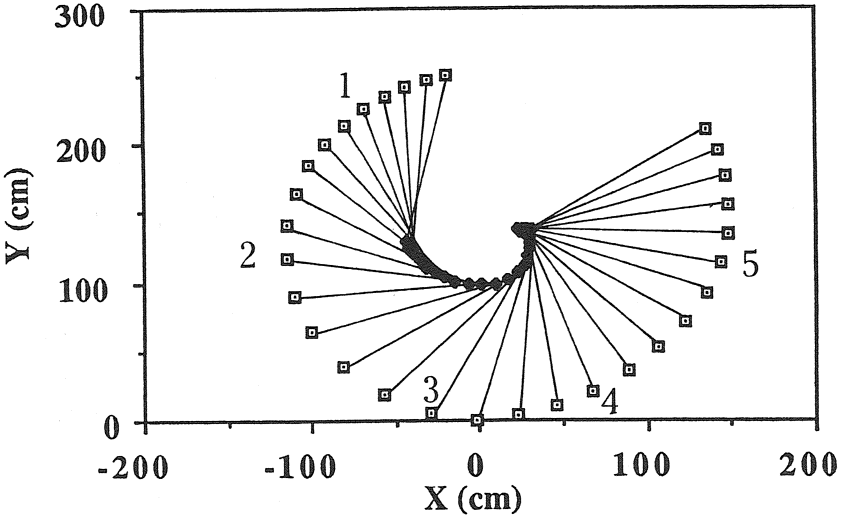


Figure 2 — Clubhead and hub paths (a); hub, vertex, and chin paths (b); vertex and





chin paths (c); and stick figures of the club for every second sample (d) of a typical novice golfer. Sequentially numbered events represent a time interval of 50 ms.

ranged from 5.2 to 14.4 cm for the novice subjects compared to 3.6 cm for the elite group. However, certain trends were common among the novice players. The hub tended to be in front of the ball at impact (mean = 5.9 cm, *SD* = 5.2 cm) and was not significantly different from the elite players. As with the elite players, the hub was moving forward during impact. However, while the hub began its forward movement from about the same position (novice: mean = –7.1 cm, *SD* = 6.8 cm; elite: mean = –8.9 cm, *SD* = 5.6 cm), it did not move as far forward ($p<.05$) in the period following impact for the novices (mean = 19.5 cm, *SD* = 7.1 cm) as it did for the elite players (mean = 28.4 cm, *SD* = 5.2 cm).

During the time approaching impact the hub did not move as high for the novice players and, as a consequence, the radius (mean = 118.7 cm, *SD* = 18.3 cm) was significantly less ($p<.01$) at impact than was that of elite players (mean = 139.5 cm, *SD* = 4.8 cm). The radius of novice players tended to reach a maximum after impact rather than at the time of impact.

The higher position of the hub at impact for the elite players reflected a flatter path of the clubhead approaching impact. This was indicated by the slope of the secant joining the position of the clubhead at the time of its minimum x (backmost) position attained during the downswing to the position at impact. The slope of this secant for the novices (–1.06, *SD* = .09) was significantly steeper ($p<.05$) than that of the elite players (–.97, *SD* = .06). The same procedure applied to the upswing, using the location of the clubhead at its maximum x position, showed that the slopes were similar for novices (.97, *SD* = .04) and elites (.95, *SD* = .04). It may be expected that the more curvilinear path up to impact would contribute to inconsistency in the shots of novice players.

Analysis of the stick figures of the whole club (e.g., Figure 2d) revealed there was less forward movement of the club during the approach to impact among novice players than among elite players, contributing to steeper clubhead paths approaching impact. Also, novice players did not rotate the shaft as rapidly by wrist action. This meant that the shaft was less vertical (when viewed from a position perpendicular to the swing plane) at impact for the novice players than for the elite players. That is, the novices were not able to get the clubhead "through" to the same extent as the elite players.

At impact the hub was located at a mean of 9.4 cm (*SD* = 7.1 cm) in front of the chin and 35.4 cm (*SD* = 17.2 cm) below the chin. This was significantly different from ($p<.01$) those of the elite players (15.9 and 17.3 cm, respectively). That is, elite players had the hub further forward and higher than novice players.

The novice players tended to begin the swing with the chin in a significantly more ($p<.01$) forward position with respect to the resting position of the ball (mean = –3.5 cm, *SD* = 5.0 cm) than the elite players (mean = –11.0 cm, *SD* = 3.1 cm). This was despite the fact that elite players moved the chin significantly further forward ($p<.01$) during the downswing (mean = 18.2 cm, *SD* = 5.9 cm) than novices (mean = 7.9 cm, *SD* = 5.8 cm). Whereas the elite players began the forward movement from a position in which the chin was 29.3 cm behind the ball (*SD* = 8.1 cm), the novices began their forward movement of the chin from only 11.4 cm (*SD* = 10.4 cm) behind the ball. These differences were due to a greater backward movement of the body during the backswing of elite players compared to novice players. Novices also had a significantly smaller ($p<.01$) forward movement of the chin after impact (mean = 17.6 cm, *SD* = 11.5 cm) than did elite players (mean = 30.9 cm, *SD* = 6.7 cm).

The above findings were consistent with the qualitative analysis. This indicated that novice players did not move forward during the shot to the same extent as the elite players, thereby giving the impression of ''playing off the back foot.'' The fact that elite players had a much greater range of lateral movement during the swing than novice players suggested that imagining a swing as a rotation about a fixed point may not be an appropriate practice, as this may inhibit the natural lateral movement associated with elite performance.

Conclusions

A method of locating the focal point (hub) of the swing was developed. It was found that this point was not static but instead moved throughout the swing in a manner that was consistent among the elite players. Thus the hub cannot be regarded as a fixed point on the body, as suggested by Cochran and Stobbs (1968) and Wiren (1990). From the results of this study it would appear that the left nipple (of a right-handed player) is a reasonable approximation of the hub position of elite players at the time of impact (Figure 3).

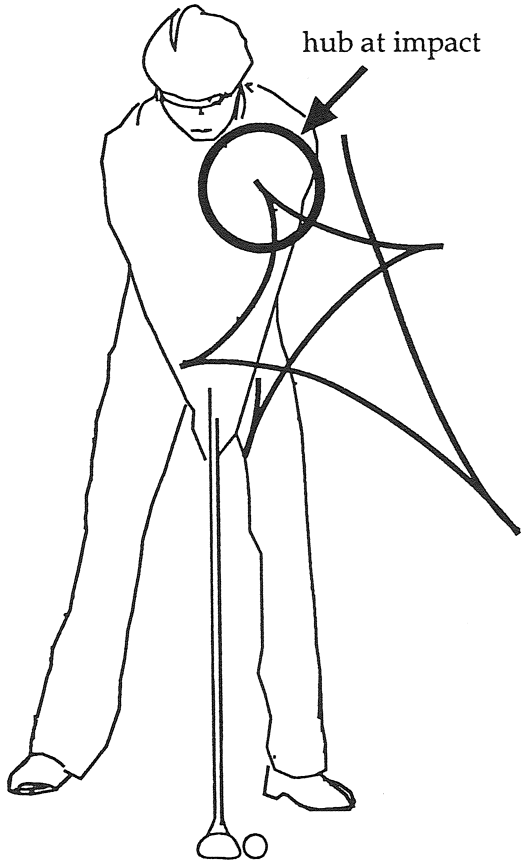


Figure 3 — Typical hub path of an elite player superimposed on a player's body position prior to the backswing.

It is suggested that rather than encouraging a swing about a fixed hub, coaches should encourage controlled lateral movement of the body toward the intended direction of the ball's flight. The head should also move in this direction but should be stabilized through the period of impact. The ideas of keeping the head still and swinging about a fixed point should be abandoned as coaching strategies because they unnecessarily constrain the natural lateral movement that is characteristic of elite players.

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