GOLF SWING MECHANICS: THE PATH TO THE FUTURE GOLF SWING

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KEY WORDS: golf, biomechanics, optimum, future golf swing.

INTRODUCTION: During the early history of the game, the tools on the market to play golf had little in similarity to those in use today. The clubs were thick-shafted, one-piece poles with extended heads - more like hockey sticks than golf clubs. The players wielding them wore constricting woollen jackets, and it was considered a feat of great skill and strength to hit a golf ball, an only roughly spherical leather object stuffed with feathers, longer than a distance of 150 yards. The preferred grip during this era was one that had all ten fingers on the handle.
By the mid-1850s, the golf swing had begun to take on the attributes of the modern form. Clubs were built that were lighter and more flexible. Balls were more spherical as they were manufactured by machine. Also, they were made of gutta percha, which produced a much more consistent ball flight. These conditions allowed Harry Vardon to develop a swing that was the precursor to the "modern" golf swing. The backswing was more upright, and he overlapped the hands on the grip. As Harry Vardon won six British Opens between 1896 and 1914, aspects of his technique were readily accepted as optimal without much debate (Bowden, 1976).
Since then the golf swing has evolved gradually, the champions of each era setting the trend for the next generation of golfers. In the 1920s, it was Bobby Jones with an inside takeaway, large hip turn, and rhythmical arm-swing. In the 1940s, it was essentially Ben Hogan, who also took the club back on the inside and swung on a shallow swing plane, but in addition advocated theories such as coiling the upper body against the hips, and generating power through vigorous hip rotation. In fact, Hogan's coaching book The Modern Fundamentals of Golf (Reprint edition, 1985) formally introduced the notion that in a powerful golf swing the big muscles generate the power, which is transmitted sequentially from the large to small body segments culminating in the production of massive club head speed at impact. Later, when Byron Nelson was recognised for his winning feats, his straight takeway and more upright swing plane became known as the modern swing. Then came Jack Nicklaus, who dominated the game for almost 20 years, and his upright swing and mechanical theory that the legs generate the power further entrenched the 'big muscle' power hypothesis in the coaching literature (Nicklaus, 1976). Finally came Tiger Woods, who is the number one golfer in the world today, and his full swing with its vigorous lateral thrust and rotation of the hips is considered by many golf professionals to be the optimum golf swing. Interestingly, both Nicklaus and Woods used interlocking grips, but this has been rarely attributed to their success.
The top player or players of each generation have largely influenced the evolution of the golf swing. Biomechanists have had little direct influence on the development of golf technique. However, biomechanics has been used to justify the success of the latest golf champion or the latest coaching paradigms. In this way, it has played its role in reinforcing the current perspectives by creating qualitative models. The question is whether these qualitative models stand up to formal or quantitative scientific scrutiny.

EVOLUTION OF QUALITATIVE MODELS: It is hardly known that the concept of a transition movement between the backswing and downswing phases was documented by Fowlie (1922), who wrote perhaps the first scientific treatise on the golf swing. He explained that the downswing is begun before the backswing of the club has ended, which is indicated by the bending out of the left knee towards the target (Figure 1). This movement was evidence of a small lateral shift and turning of the hips to the left before the backswing had been completed. This move was thought to prove that the hips generated power during the downswing, which was transmitted proximally to distally from the trunk to the hands causing them to swing passively with great speed. This is known as big muscle theory, and is metaphorically referred to by modern elite coaches as "the dog wagging the tail" (Leadbetter, 1990; Mann and Griffin, 1998). Though most early teachers emphasised swinging the golf club with the arms and hands, Fowlie had proposed a body-actuated golf swing theory over 80 years ago.

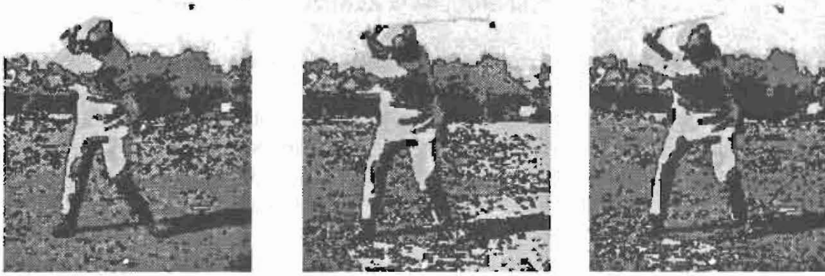

Figure 1: James Braid had a small transition move just prior to the downswing - the separation between the knees increases (Fowlie, 1922).

Further studies have shown evidence of a small transition movement in most good golf swings (Cochran and Stubbs, 1968). However, the transition move is small and subtle. Modern transition drills require the golfer to start turning the hips towards the left while the club is only three-quarters of the way up in the backswing (Mann and Griffin, 1998). The idea is that the strong torqueing of the shoulders on the hips stores energy, which can be released during the downswing. This mechanical theory serves as the foundation of the X-factor, which states that the longest hitters increase the separation angle between the shoulders and hips at the top of the backswing through the forcible restriction of the hips (McLean, 1992). Apart from the large strains imposed on the lower lumbar region, the X-factor theory does not consider which muscles are stretched, the different planes of motion of the hips and shoulders during the downswing (Kuykendall, 2000), and that most golf coaches recommend a smooth controlled start to the downswing (Snead, 1946; Flick, 1997).
Further support for the theory that the trunk or twisting of the trunk segments against each other is responsible the most of the power generation in the golf swing, (which also tended to complement the X-factor), is the notion that trunk rotation can create a large enough centrifugal force to extend and rotate the arms through impact. David Leadbetter (1990) explains that the coiling and uncoiling of the torso in a rotary or circular motion maximises centrifugal force because it is a force created away from the centre of your swing. He therefore concludes that this force is transmitted from your body, out through the arms and hands, creating leverage, width of arc and club head lag. In turn, this creates club head speed and maintains the club on a steady orbit or arc. The theory of body-generated centrifugal force has led many modern golf theorists to stress the importance of pulling with the left side, and keeping the right side passive during the downswing (Flick, 1997). The right arm is supposed to remain passive throughout the golf swing. An active extension and rotation of the right arm is sometimes considered to be the bane of golfers leading to problems with timing, and causing slices. However, preliminary analysis suggests the hips and trunk have relatively low angular velocities, which are insufficient to create a significant centrifugal contribution to club head speed.
Though centrifugal force is fictitious in the sense that it is calculated in a non-inertial frame of reference (Baruh, 1999), and not an actuating force, it has been used to predict the effect of system dynamics. For instance, Cochran and Stubbs (1968) stated that in a rotating frame of reference (non-inertial), the centrifugal force predicts a straightening out of the levers in a two-lever model (Figure 2). An older theory put forward by Jones and Brown (1948) is that the arms can move sufficiently quickly in a golf swing to generate this centrifugal effect, while the body merely moves in response to support the arm motion (Figure 3). The theory is that if the arms generate the majority of the power in the golf swing, then extension of the right arm, and right hand may not be entirely due to muscle action. However, other dynamics properties of the

arm-club lever system may better support this theory.

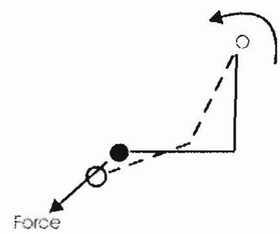

Figure 2: Cochran and Stubbs (1968) state that the centrifugal force calculated in a non-inertial frame of reference (attached to O) acts outwards on the club head, which straightens out the hinge. Note that centrifugal force only represents the effect of club head inertia. The actuating torque is applied about O.

To optimise the arm motion to generate clubhead speed, Jones and Brown (1948) suggested that the Vardon overlapping grip promotes a more rhythmical swinging motion of the club (Figure 3). Traditionally, the golf swing has been modelled as a free hinged two-lever system composed of a straight left arm, and club (Cochran and Stubbs, 1968; Jorgensen, 1970). However, this could ignore the strong contribution of the right arm during the period of maximum club head acceleration . To facilitate forearm rotation, and the passive uncocking of the wrists, almost all the coaching literature emphasises the placing the handle of the club more towards the fingers of the right hand.

In summary, early methods on how to play golf emphasised using the arms to swing the club with the body moving in reactive support. This teaching was popularised by Ernest Jones (Jones,1952). However, this was replaced with more body-oriented swing theories in which the hips and trunk supplied the power, and the arms moved passively. The modern trend is to take this to the extreme by torqueing the shoulders against the hips to release the stored energy during the downswing.

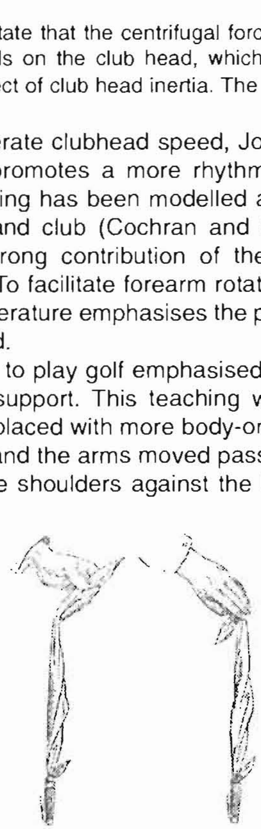

Figure 3: Jones and Brown (1948) believed that the mechanics of swinging a hanky were similar to that in a golf swing. Leverage (left) when applied to a hanky did not produce motion, but a swinging motion (right) keeps the hanky taut. [Picture from Swinging into Golf, Ivor Nicholson Watson, London].

THE NEW QUALITATIVE MODEL: There have been several demonstrations to show that the arms generate most of the power in a golf swing. Ernest Jones lost a leg during military service, but reported that he could still hit a ball almost as far as before (Jones, 1952). Jones believed strongly that the hands control the swing, with the large muscles of the body - upper arms, shoulders, and legs - performing as "admirable followers." He also demonstrated that he could hit the ball almost as far while sitting down. Seve Ballesteros took this further by consistently driving a ball over 240 yards while on his knees (Wiren, 1997). Though these demonstrations are impressive, they are not conclusive evidence that the body produces little or no power in the golf swing. The planes of motion of the shoulders and hips may be different when sitting down compared to that when standing up. However, observations tend to suggest that there is a significant relative difference in the planes of motion of the shoulders and hips during the power phase of the downswing (Kuykendall, 2000). When the club head is undergoing its highest period of acceleration, the hip rotation plane is almost horizontal, and the shoulder rotation plane almost vertical. Therefore, velocity contribution of the hips to club head speed during this period would be small.

Hence, a qualitative golf swing model would tend to support the arm-dominant swing theorists, who propose that the body responds to the swing of the club head rather than the other way around (Jones and Brown, 1948; Flick, 1997). Also, this school of thought contends that the arms can move much faster than the rotation of the trunk or hips. Hence, Leslie King, the notable English golf teacher, proposed that the start of the downswing is begun with the motion of the left arm while the shoulders remain in a closed position at the top of the swing (Golf pro-Online, 2000). He also emphasises the need to feel the arms swinging somewhat independently of the shoulders. Jack Kuykendall (2000) also subscribes to this theory of allowing the body to move in response to the initial movement of the hands down and away from the right shoulder, but in relation to a technique that has the left arm bent up to 90 degrees with the hands near the right shoulder, and the elimination of left wrist cock (Anonymous, 2000).

The concept of swinging the arms independently of the body is one that makes sense from a preliminary qualitative analysis. Early field-testing indicates that this downswing move is powerful, but only in the context of the mechanics of the total swing. However, even this downswing move may be an over-simplification. A dynamics model of the golf swing is being used to test whether there is also an active lateral motion of the hips, and when this is initiated.

A qualitative model of the golf swing does not therefore support a strong torqueing of the shoulders on the hips, which (i) places large stresses on the shoulders and back, and (ii) could tend to rotate the shoulders early on a more horizontal plane promoting the club to travel on an outside-to-in path. Hence, if there is no need for an excessive coiling of the trunk muscles, then it would be biomechanically plausible to bend the left arm slightly to enable the arms to swing more independently of the body. The amount of left wrist cock must not be reduced. Golf teachers today are now more open to the idea of a slightly bent front arm (Toski and Love, 1997; Hogan, 1992). However, there was also a time when the bent front arm with a full wrist cock was the established technique, and for much the correct reasons (Howell, 1921).

As the model encourages the use of the arms to generate the power, the lower body acts more in reactive support. Many teachers suggest the use of a slightly wider stance to increase stability, particularly for the driver or for strokes requiring maximum power (Natural Golf, 1997; Kuykendall Golf, 2000; Graves Golf, 2000, Woods, 2001). This is consistent with the idea that golf is a more a small muscle game in which the big muscles play more of a supporting role (Flick, 1997).

The future golf swing, subject to empirical testing, is likely to embody most of the following attributes:

1. The stance is slightly wider than conventional to improve stability.
2. Either Vardon overlapping, interlocking, or baseball grips can be used, and thin handles are not necessary. The handle is placed towards the fingers of the right hand, and more horizontally across the palm, as is often conventionally recommended with the groove or 'V' between the thumb and forefinger pointing approximately to the right shoulder.
3. A conventional-type backswing where the club is taken gradually back inside the line of flight, and on plane.
4. The front arm is allowed to bend only slightly at the top of the backswing, and left wrist allowed to fully cock. This gives a virtual three lever front arm further reducing the moment of inertia about the left shoulder joint. It is important that the hands are some distance away from the right shoulder.
5. A swinging downswing-move using the three lever front arm in conjunction with a lateral slide of the hips.
6. The hit is made against a firm left side by locking the hips so that a stable base of support is achieved at impact.

7. Hip rotation becomes significant only after the weight has been transferred to the outside edge of the front foot, and after impact.

CONCLUSION: Qualitative biomechanical analysis of the golf swing suggests that an optimum swing model can be designed to simplify the act of striking a golf ball with a potential increase in performance. The venture to design an optimum golf swing model is part of a five-year project, which includes extensive three-dimensional testing, and the further development of dynamics models capable of inverse and forward solution. This is the only means to scientifically determine the various mechanical characteristics of the golf swing, such as segmental velocity contribution, timing and duration of the active and passive segment power phases, switching times of the major muscle groups, and relative segmental planes of motion. The mere observation of videos, and photographs is not sufficient to provide a scientific basis of a golf swing model. Many mistakes have been committed by using this approach. The biomechanics of the new millennium has many sophisticated tools at its disposal, and many excellent biomechanists to optimise the mechanics of the golf swing.

There is much more to learn about the mechanics of the golf swing. In golf there have been many great teachers and players who have come up with various techniques and theories to optimise the performance of the golf swing. Many of these are correct, as should be expected for golf has been played in its modern form for over 100 years. However, it only takes one incorrect piece of information to make a whole golf swing system invalid or difficult to perform. One objective of the optimum golf swing model is to provide the correct information on the mechanics of the golf swing so that the invaluable advice of the past masters of the game can be implemented in the right context. Also, it is expected that the optimum golf swing model can be simulated to perform a perfect swing. Already the model predicts that golfers such as Jim Barnes, Byron Nelson, Moe Norman and others incorporated aspects of an optimum golf swing technique. Also, field-testing of the optimum golf swing model has shown that golfers find it a simpler swing to learn, and are reporting significant increases in performance. However, do not expect the future golf swing to look so radically different that it lacks all rhythm and tempo. Instead, the future golf swing will still look like a golf swing. The differences may be subtle, but clear to the trained eye, and there is evidence to suggest that it will be a more effective golf swing, many elements of which will be used by the champions of tomorrow.

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