DEVELOPING A THEORETICAL MODEL OF HUMAN MOVEMENT

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In the last 25 years, the literature in kinematic and kinetic analysis of human motion has grown in volume as well as level of sophistication. New technology facilitated faster quantification of movement parameters and greatly increased the data base from which conclusions are drawn. Sample sizes of 5-6 have been replaced by 20+ and acceptable trials for analysis is often 10 not two. Such data are not easily shared with the athlete or coach because numerical or graphic presentation of velocity, force or acceleration is not readily translated into strategies for training, practice or competition.

Sport biomechanists have rarely approached human movement from a theoretical standpoint. Theories are developed in two ways. One approach starts with a theory and through several replications of results demonstrates it to be true in a universal set of reality situations. A second approach begins with numerous observations of movement situations which have some thread of commonality and progresses toward a formal theory. The latter approach was utilized in developing the movement theory labeled the "figure-eight pattern." It arose from Dr. Wu's thoughtful and critical observation of Taiji, was extended to a variety of sport examples, and eventually verified using the mathematics of topology. It accepts the common constraints of bone, muscle and ligaments and proposes a process which can be used in performing sport and daily life activities.

Discovery begins by asking simple questions. How do you draw a circle? Use an index finger to draw or follow a circle in the counter-clockwise direction. Using this point representation of movement we have drawn a circle (a series of points); however, the circle is basically the product of drawing. The process of drawing is still unclear. Now use the hand to trace the circle (counter-clockwise) allowing a line to represent the hand - a line with ends T (thumb) and L (little finger) (Figure 1). Constraints of bones, muscles, tendons and ligaments do not allow us to draw a 360° circle without adjusting or switching the hand position at least once during the drawing process. Observe that the thumb (T) starts inside the circle to be traced, but is outside the circle 180° later.

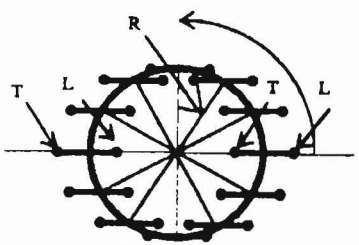

Figure 1. Circle drawn with line representation of the hand.

Using equal time intervals, Figure 2 represents a hand position from t_1 to t_2 in which the switching of hand position occurs at t_7. With practice it is easy to demonstrate

that the circle can be drawn with many points of switching (crossing the line of the drawn circle), but never without switching the hand, i.e. the line.

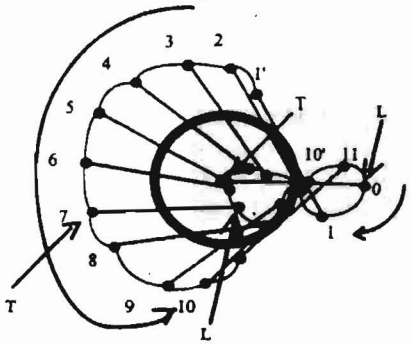

Figure 2. Switching feature of the hand drawing a circle.

In topology this concept is demonstrated by the winding number. Figure 3 demonstrates a winding number of 1 in which the L (little finger) is always outside the drawn circle and T (Thumb) is aways inside the drawn circle; it never switches. A winding number of 0 is the case in which the line representation of the hand switches or crosses the drawn circle at least once (Figure 4). Using the winding number to test movement patterns from different sports and daily life skills it is clear that humans move in topological patterns which have a winding number of 0, i.e. human movement requires some element of switching the position to complete the pattern. Now we have a tool which can describe how the circle is drawn - the "figure-eight pattern."

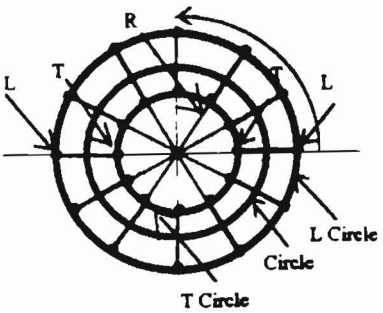

Figure 3. Circle drawn with winding number=1.

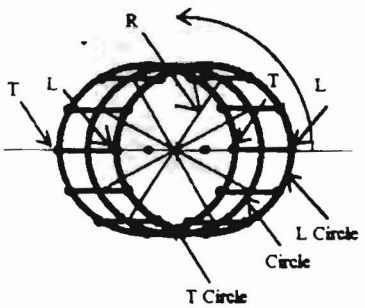

Figure 4. Circle drawn with winding number=0.

To improve the efficiency and effectiveness of a movement pattern, we combined the switching feature with a mechanical crank system. This combination allows for both rotation, either clockwise (C) or counter-clockwise (CC), and translation. Using the line representation of the right and left hip Figure 5 shows the regular figure-eight pattern in which the left hip first moves counter-clockwise (LCC) and the right hip moves clockwise (RC). This pattern (LCC/RC) is especially effective in moving the body forward by lifting the heel and pivoting the foot with proper timing.

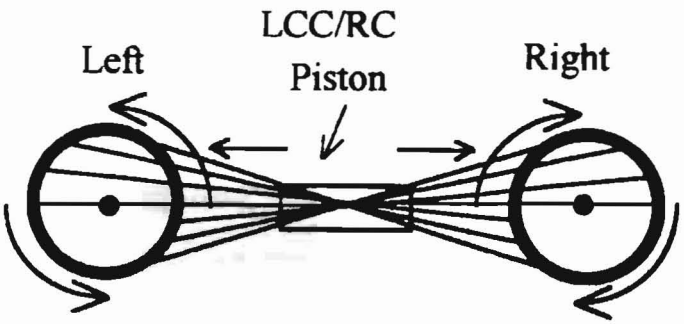

Figure 5. Regular figure-eight action of the left and right hips (LCC/RC).

The reverse of this pattern is shown in Figure 6. The left hip moves clockwise (LC) and the right hip moves counter-clockwise (RCC), i.e. pattern of LC/RCC. This reverse figure-eight pattern is useful in propelling the body backward.

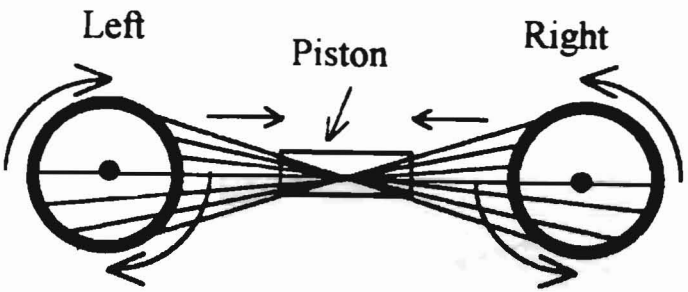

Figure 6. Reverse figure-eight action of the left and right hips (LC/RCC).

A final verification of the success of the figure-eight pattern or theory is to determine its ability to predict outcome. A forehand racquet stroke for a right-handed player uses the basic figure-eight pattern (LCC/RC) with the right hip as the driving force and ball contact off the left foot (Figure 7). A backhand racquet stroke for the

same player uses the same regular figure-eight pattern (LC/RCC) with the left hip driving the force and ball contact in front of the right foot (Figure 8).

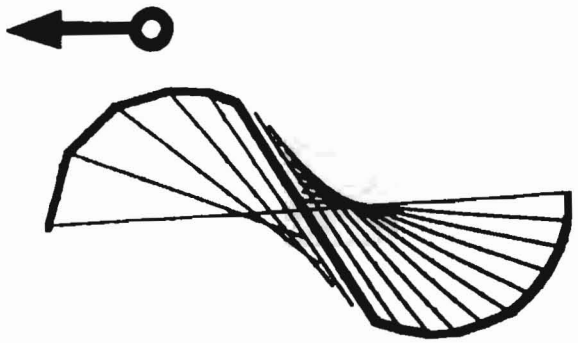

Figure 7. Forehand stroke using regular pattern (LCC/RC).

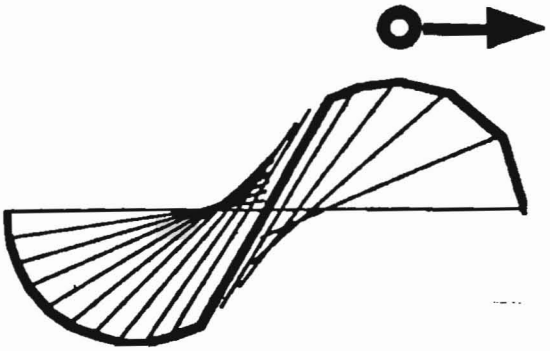

Figure 8. Backhand stroke using regular pattern (LCC/RC).

Observing the pattern carefully in equal time segments the line between the left and right hips also identifies which hip has greater velocity at a given point in the pattern. The reverse figure-eight pattern (Figures 9 and 10) provides the player with two additional ways to execute ground strokes. Michael Chang has frequently demonstrated this reverse pattern in his powerful tennis stroke. As a result he effectively adds another method of performing the forehand and the backhand.

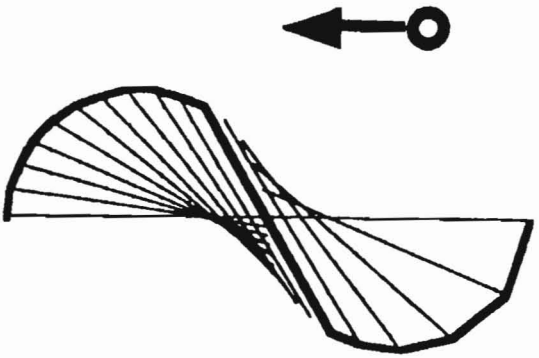

Figure 9. Forehand stroke using reverse pattern (LC/RCC).

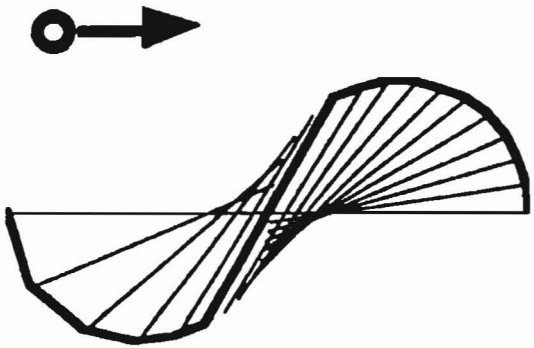

Figure 10. Backhand stroke using reverse pattern (LC/RCC).

Extensions of the figure-eight pattern have been made by the authors to other skills such as the flutter kick and roller skating as well as daily life skills of floor mopping in which progress forward or backward is desired. Once the goal is described the best figure-eight pattern (Regular or Reverse) can be identified. Consider the time saved in learning new movement patterns if the teacher or coach had students who knew the two basic figure-eight patterns. Using these patterns in a new situation would quickly follow, thus allowing more time for strategy. In push-hand Taiji partners work against each other. Sometimes they control by forceful or aggressive moves and other times by avoidance behavior. The figure-eight theory has been useful in both teaching the movement patterns and demonstrating strategies required for these two very different actions.