

**TABLE TENNIS:
A BRIEF OVERVIEW OF BIOMECHANICAL ASPECTS
OF THE GAME
FOR COACHES AND PLAYERS**

MARION ALEXANDER, PHD

ADRIAN HONISH, MSC

SPORT BIOMECHANICS LABORATORY

FACULTY OF KINESIOLOGY AND RECREATION MANAGEMENT

UNIVERSITY OF MANITOBA



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TABLE TENNIS BIOMECHANICS

1. HISTORY

Today's popular sport of table tennis has grown considerably since its birth late in the nineteenth century by the upper class in England. It began as a recreational activity and social diversion during the 1880's when adherents of lawn tennis adapted their pastime to be played indoors during the winter season. Referred to as Whiff-Whaff or Gossamer the game was played with balls made of cork or rubber and wooden paddles covered with dried animal skins (Wikipedia, 2009). After J. Jacques & Son introduced the name Ping-Pong (an imitation of the sound of the ball contacting the table and paddle), the game's popularity began to rise (Robbins, 2004). Parker Brothers copyrighted the name "ping-pong" in 1926 and it was to be used exclusively for games manufactured by their company (Boggan, 2000).

The name table tennis was adopted after a brief period following 1910 when interest levels in the game dropped dramatically. The game was revived in England and Wales in the early twenties with its current name of table tennis. National associations were formed and standardization of the rules began to develop in both Europe and the Far East (Boggan, 2009)

In 1926, the International Table Tennis Federation (ITTF) was formed in Berlin and international laws were adopted. That same year, the first official World Championships were held in London. By this time balls were composed of celluloid and the paddles consisted of sheets of pimples rubber glued to wooden blades. Development over the last few decades have seen paddles made with "sandwich" rubber (pimpled rubber attached to a layer of sponge), rubbers specially treated to impart extra spin or to absorb spin, and "speed" glues which were absorbed into the sponge to make the rubber springier and add speed to the ball (Robbins, 2004).

In 1926, seven countries attended the World Championships, today 160 countries are represented by over 650 players (47th World Championships, 2003), and in 1988, table tennis became an Olympic sport. The top countries in the world in table tennis for both men and women are China, Korea, and Japan; with a few top men also from Sweden and Germany.

The overall development of the sport of table tennis is evident throughout its history. However, the game itself has not changed in essence since its early days. Although it is faster, more subtle and more demanding than it was in previous decades, it has always been the concern of the ITTF to ensure that table tennis remains a contest of human skills and not that of the technology surrounding advances in equipment. Thus, equipment specifications have been carefully described in detail and enforced by the ITTF (Robbins, 2004). Future development of competitors must therefore be focused on their individual physical abilities and advancements in the biomechanics of the game itself.

REACTION TIME

Reaction time is an accurate indicator of speed and effectiveness of decision making. Reaction time (RT) is the elapsed time between the presentation of a sensory stimulus and the subsequent behavioral response. It is defined as the interval between the presentation of an unanticipated stimulus and the beginning of the response (Schmidt & Wrisburg, 2004). For over 120 years the accepted reaction time of college-age individuals for visual stimuli has been between 180 ms and 200 ms and for auditory stimuli, between 140 ms and 160 ms (Brebner & Welford, 1980; Fieandt, Huhtala, Kullberg, & Saarl, 1956; Welford, 1980; Woodworth & Schlosberg, 1954). An important observation to be made from these findings is that reaction times to auditory stimulus are much shorter. This is likely due to the fact that an auditory stimulus only takes 8 – 10 ms to reach the brain (Kemp, 1973) while a visual stimulus takes 20 – 40 ms (Marshall, Talbot, & Ades, 1943). Table tennis players rely largely on the sound of the contact between the ball and the opponent's paddle to identify shot types, shot velocity, etc. Using this auditory feedback allows them to react much more quickly and allows them to use more of their available time to execute the shot as opposed to reacting to the circumstance.

Sports such as table tennis, badminton, tennis, squash, and racquetball have been classified as reaction sports (Yoshida et al., 1995). In table tennis specifically, the incredible speed of the ball and the short distance it travels between opponents allows a very minimal amount of time to react and execute shots. A study by Xiaopeng (1998) at

the Chinese Table Tennis Association, National Research Institute of Sports Science measured ball velocities of 10.4 m/s for the forehand attack shot and 17 m/s for the forehand smash. When using the dimensions of an official table tennis table (274 cm in length) and assuming that a ball is contacted 30 cm from the end of each side (an assumption for the sake of this example), the time required for the ball to travel between opponents can be calculated. Using the formula: $V = d/t$, (Velocity = distance/time), time is equal to the distance the ball travels divided by its velocity. Knowing that the ball travels 334 cm with a velocity of 10.4 m/s and 17 m/s for the forehand attack shot and smash respectively, it will take 320 ms and 196 ms respectively for the shots to travel between opponents. Since the average reaction time is 180-220 ms, it is clear the player barely has time to react to the visual stimulus of the ball before the ball has arrived to be hit. Without much further explanation it is not difficult to appreciate the speed of this sport and the demands that are placed on its competitors.

There are several factors that can affect the reaction time of a table tennis athlete specifically. An individual's state of arousal, or attention, as well as muscular tension has been shown to have an influence on reaction time. The inverted U principle, as shown in Figure 1.1, illustrates an increase in performance corresponding with decreased

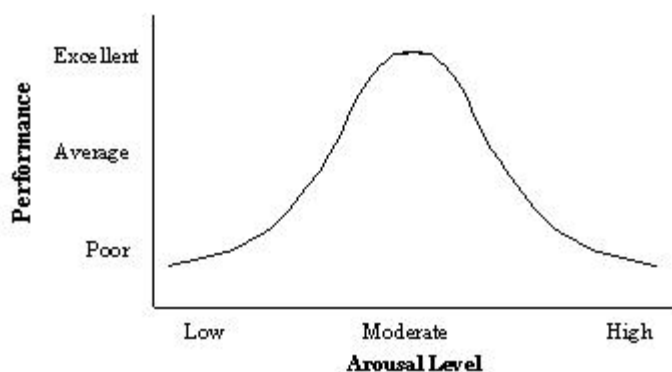


Figure 1.1 Inverted U principle. Performance is highest at moderate levels of arousal (Schmidt & Wrisburg, 2004)

reaction time as arousal level rises from low to moderate and then a drop in performance as arousal level rises past a moderate level. When one either becomes too relaxed or too tense, possibly resulting from high anxiety, performance levels become lower (Broadbent, 1971; Freeman, 1933; Schmidt & Wrisburg, 2004; Welford, 1980).

One of the most important factors influencing the time it takes to start an action is the number of possible stimuli that the performer may be presented with. In the game of table tennis, the athlete

needs to react to a variety of different shots with varying ball speed, direction, trajectory and/or spin. Each of these factors and their numerous combinations require a different response and motor pattern to execute an effective return. Situations such as this illustrate choice reaction time, where the performer must identify the stimulus that is presented and then choose the response that best corresponds to the stimulus. Longer reaction times result from a greater number of stimulus-response alternatives (Schmidt & Wrisburg, 2004). This relationship is known as Hick's Law, which implies that choice reaction time increases by a constant amount every time the number of stimulus-response alternatives is doubled (eg. from 2 to 4 or from 8 to 16). Therefore, choice reaction time is linearly related to the amount of information that must be processed to resolve the uncertainty about the various possible stimulus-response alternatives (Schmidt & Wrisburg, 2004). This emphasizes the importance for table tennis strategy to involve the use of a variety of different shots with each stroke performed as similarly as possible in order to disguise shot-related information from the opponent.

Reaction times are affected by direct versus peripheral vision. It has been shown that reaction times vary depending on what portion of the eye picks up the stimulus. Reaction times are shortest (178 ms) if the stimulus is picked up by the cones of the eye directly in front of the line of vision (Ando, Kida, & Oda, 2002). This is called central vision. As the stimulus moves more peripherally reaction times increase with the angle of the stimulus from central vision. Ando (2002) measured reaction times of 185 ms with the stimulus at 10-degrees from central vision and 197 ms at 30-degrees peripherally. This finding suggests that table tennis competitors will be able to react faster to their opponent's shots if they keep their eyes directly on the ball until after the ball is hit.

Practice and error has been found to improve reaction times. Ando (2002) conducted a study that monitored the effects of practice on a simple reaction time test. The test required subjects to react to a visual stimulus on a computer screen that was presented either centrally or peripherally by pressing the space bar immediately after the stimulus was presented. They found decreases in reaction time for both central and peripheral stimuli after practicing the task. Reaction time to a central stimulus was reduced from 178 ms to 167 ms, while reaction time to a peripheral stimulus decreased

from 185 ms to 169 ms (10-degrees peripherally) and from 197 ms to 179 ms (30-degrees peripherally).

Although inconclusive, some studies have shown exercise to have a positive effect on reaction times. Physically fit subjects tend to have faster reaction times than less fit subjects (Welford, 1980). A study by (Hascelik, Basgoze, Turker, Norman, & Ozker, 1989) found decreases in the visual reaction time of male volleyball players from 214.55 ms to 200 ms and in auditory reaction time from 191.3 ms to 175.05 ms following an 8 week exercise program comprised mostly of weight training. They also cite several studies that show improvements in reaction time of up to 7 % following high resistance isometric training. This has definite implications to the game of table tennis. Much like the importance of arousal, athletes must maintain a certain level of physical fitness in order to best prepare themselves to react.

Finally, fatigue can negatively affect reaction time. As an athlete becomes tired or fatigued, reaction times have been shown to decrease (Welford, 1980). A study by Singleton (1953) suggests that reaction times decrease even more substantially when the task is complicated rather than simple. The tasks performed in a table tennis match are quite complex in the sense that they require finely detailed movements with little to no room for error in order to execute shots efficiently.

In order to maximize performance, table tennis coaches and athletes alike need to be concerned with the principles that affect reaction time. As discussed earlier, table tennis can be classified as a reaction sport and athletes have to not waste any time in extra movements. Earlier it was calculated that it takes approximately 0.32 sec for a forehand attack shot and 0.196 sec for a forehand smash to travel from one end of the table to the other. If one were to subtract an average auditory reaction time of 0.14 sec to 0.16 sec from this interval, the player is only left with 0.16 sec to 0.18 sec to play the attack shot and 0.056 sec to 0.036 sec to defend against the smash. This illustration clarifies the importance of manipulating factors decreasing reaction time as much as possible in order to decrease the time that will be required for reacting and maximize the time available to play the ball.

General Comments on Technique:

Skilled athletes in most sports are characterized by a larger range of motion in their shots- there is a longer backswing and a longer follow through indicating a more powerful shot; and one that is more accurate due to the longer swing. There is usually a greater range of trunk rotation that will produce greater force into the skill. In table tennis the stroke usually goes from low to high- from behind the athlete below the table to well above the player's head, in order to place the required spin on the ball.

Skilled athletes have a wider stance during their shots and in the ready position than less skilled players. Stance should be as wide as the player can handle, with the trunk flexed forward and the weight on the balls of the feet. The toes are pointed slightly outward (lateral hip rotation) to enable faster movement in a lateral direction. The knees and hips are flexed as low as possible, close to 90 degrees and even more in many situations; and the trunk is also flexed forward. Many shots are taken from this wide stance, some are taken with a step into the shot as is seen in tennis. Many shots in table tennis are taken from the wrong foot, or the back foot, which would be the right foot for a right handed player's forehand. Shots taken from the back foot allow for a greater range of trunk rotation and trunk extension during the shot, which will provide additional force. Comparisons of younger athletes to world class athletes are often related to the length of the backswing and the width of the stance during the shot execution.

Many of the shots in table tennis are executed from a low to high pathway of the racquet in order to apply top spin to the ball. The racquet starts in a low position at about the level of the back knee and moves up through the ball to finish in a high position in front of the body. The ball is struck while the racquet is moving upward to impart the maximum amount of top spin to help keep the ball on the table by causing it to drop more rapidly than normal.

Other arm movements that help in applying topspin to the ball are forearm pronation that often occurs during ball contact, and wrist abduction (radial deviation) or adduction (ulnar deviation). Wrist abduction is the movement of the hand towards the thumb side, so that during the forehand smash the wrist is initially adducted (moved towards the little finger side) during the backswing, then it is abducted (moved toward the thumb side) through impact to increase the force of the shot as well as the top spin on the ball at impact. The wrist movement is opposite during the backhand cut serve, it that it is

abducted during the backswing, then it is adducted at impact to impart back spin to the ball. The forearm movement is also opposite during a cut shot, in that the forearm will supinate to apply back spin to the ball.

Skilled athletes often exhibit greater forward trunk flexion than less skilled athletes, both during the ready position and during the execution of the shots. Forward trunk flexion helps the athlete to stay balanced and keep the weight forward on the balls of the feet. Trunk flexion also allows the trunk to rotate more easily as the anterior trunk muscles are already partially contracted. Trunk flexion also increases the lever arm from the axis through the active hip to the racquet, increasing the velocity of the racquet at impact. An upright stance with extended hips and knees may restrict trunk rotation and reduce the contribution of the trunk in the skill.

Skilled athletes exhibit greater anticipation than less skilled, so they are ready to return the shot earlier. Skilled athletes use the follow through motions to enable them to return to the ready position as soon as possible, so they are ready for the return as the ball is being contacted by the opponent. The backswing for the forehand and backhand stroke occurs earlier, and the stroke is not rushed.

2. SERVE

The table tennis service is a closed skill in which the player has complete control over manipulating the ball.

Schmidt and Wisburg (2004) define a closed skill as “a skill performed in an environment that is predictable or stationary and that allows performers to plan their movements in advance.” It is also one of the

most difficult skills to master in the game as the player can apply a number of different trajectories, velocities and, most importantly, directions of spin to the ball with each



Figure 2.1: Path of the ball tracked following chop serve

resulting in a much different ball flight. The direction and velocity of the spin applied to a table tennis ball will dramatically affect the path of the ball (Figure 2.1). The direction of spin will determine which way it will curve, while the amount of curve of the ball's pathway is determined by the velocity of the spin. Brancazio [, 1984 #23] noted that the rotational speed of the table tennis ball can be as large or even greater than its linear speed. The amount of spin on the ball can have an even greater effect on the trajectory and rebound than the linear velocity of the ball. Spin is applied to the ball by applying the force of the racquet to the outside of the ball, rather than to the middle of the ball. The racquet is drawn along

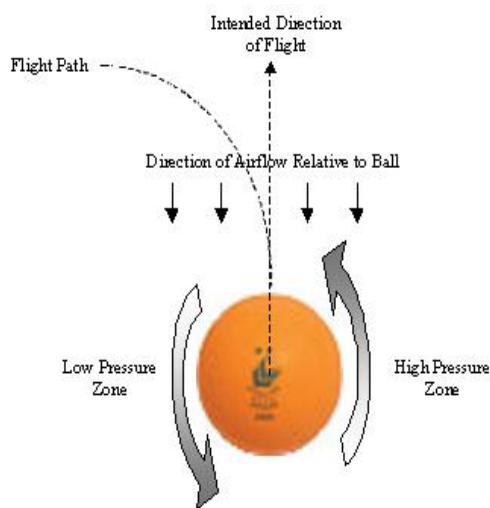


Figure 2.2. Magnus effect acting on the table tennis ball, viewed from above. Spin imparted to the ball Causes an imbalance of pressures and produces a curved path of the ball.

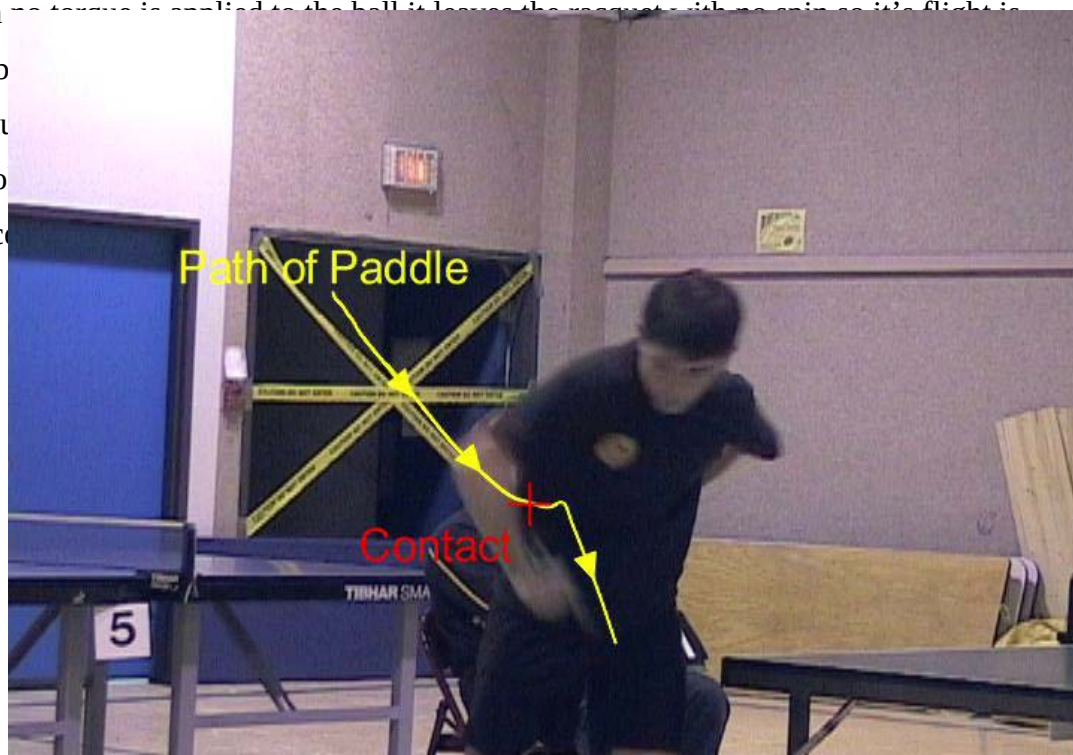
the outside of the ball to produce spin; if no spin is required the racquet will push directly through the center of gravity of the ball. Spin is applied to the ball at the expense of linear velocity- a hit directly through the center of the ball will utilize all of the racquet's velocity in producing linear velocity on the ball. If the racquet is drawn along the outside of the ball, or over the top as in topspin, more of the racquet velocity is used in producing spin on the ball.

This effect of spin on the pathway of a ball is termed the Magnus effect and is clearly explained by Hay (1993). When a body rotates, it tends to carry around with it a layer of fluid (air) that is in contact with its surface. This fluid then influences the surrounding fluid that the ball is passing through and the ball acquires a boundary layer that rotates

with it. In Figure 2.2, the arrows around the table tennis ball indicate the direction that the ball is spinning. The arrow on the left side moves in a downward direction with respect to the ball and is in the same direction as the oncoming airflow. Therefore, the oncoming air can pass much more freely at a higher speed across the left side of the ball, creating a low-pressure system on that side. The arrow on the right side of the ball points upward meaning that the boundary layer of the ball is colliding with the oncoming air. As a result, the oncoming air will not pass the ball as freely or quickly and a high-pressure system is created. The net result of this discrepancy between the pressures on either side of the ball is a resultant force acting on the ball from right to left. A body has a tendency to move from high pressure to low pressure in order to balance the pressures in the system. Therefore, the ball here will deviate in a curved path to its left.

In table tennis, the path of the paddle at contact produces the spin applied to the ball. To generate topspin the paddle must be moving upward with respect to the ball, and conversely, to perform a chop (backspin) serve, the path of the paddle must be downward. As well a variety of sidespins and diagonal spins can be applied by cutting the ball with the paddle moving in a more left to right path through the frontal plane. Figure 2.3, demonstrates the path of the paddle when applying underspin and clockwise sidespin to the ball. Another type of serve commonly used is the float serve. Much like the float serve commonly seen in volleyball, the server imparts no spin on the ball. This is performed by a much flatter path of the paddle as it approaches the ball from directly behind and contact is made directly through the center of gravity of the ball. When no torque is applied to the ball it leaves the racket with no spin so it's flight is

unstab
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A study by Yoshida (1995) examined the differences in the path of the paddle during a float serve and a chop serve. They found the contact point of the float serve to occur approximately 14.5 cm higher, with respect to the surface of the table, than that of the chop serve (~34 cm vs. ~20 cm above the table). One reason for this is the effect that the spin on the ball will have on its rebound from the table. A ball with backspin, as seen in the chop serve, will rebound higher than a ball with no spin or topspin. Therefore, in order for the server to keep the trajectory of the chop serve low he or she needs to lower the contact point much more than would be necessary in other service types.

The angle of the paddle at contact was seen to be more closed during the float serve and open during the chop serve. This difference is due to the nature of the serve. Figure 2.4 shows an open paddle angle while applying backspin to the ball such as that seen in the chop serve. The server must maintain a more open paddle face in order to apply backspin during the chop serve. It allows the player to apply an off center force to the ball to generate angular momentum and therefore spin. Closing the paddle face during the float serve will prevent this spin from occurring. During the float serve, the paddle approaches the ball with the same open angle, however right before contact the wrist and fingers rotate the paddle

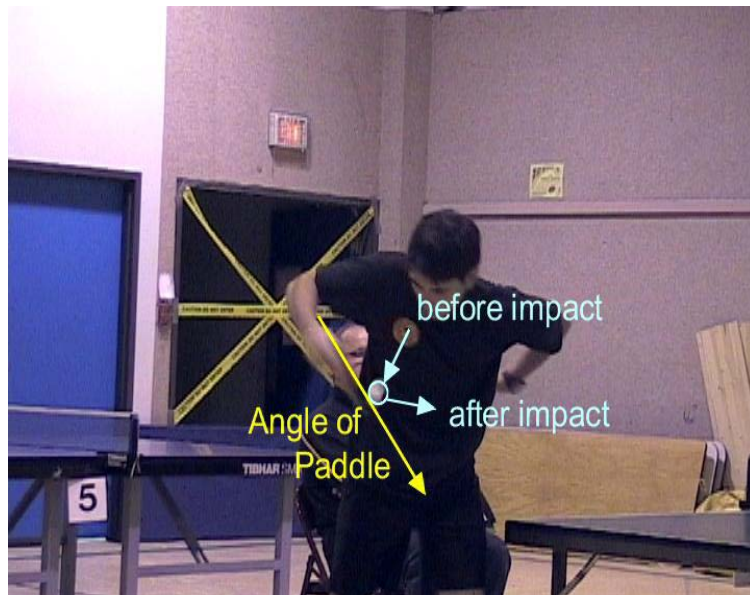


Figure 2.4: Open paddle angle allows server to apply backspin to the ball. Example, chop serve

into a more closed position at contact, contacting the ball with the upper half of the paddle. This makes the two serves appear to be almost identical to the opponent when in fact they are very much different.

Yoshida (1995) tracked the path of the paddle, measuring its vertical velocity through contact. The chop and float serves demonstrated mean vertical velocities of -0.56 ± 0.20 m/sec and 0.08 ± 0.12 m/sec respectively. These measurements illustrated that the path of the paddle was downward for the chop serve and slightly upward, or almost flat for the float serve. However, when filmed by high speed cameras from the opponents view point, the path of the paddle for both services appeared to be downward when in fact the calculated vertical velocities show that this is not the case.

In a reaction sport like table tennis where very little time is available to identify shot types (spin type, velocity, trajectory, etc.), it becomes very important for players to obtain as much information as possible from the movement of the opponent as they prepare for the next shot. Therefore, it is also important for players to think about disguising their shots or hiding this shot information from opponents. This is easier during the serve than any other strokes only because the server has complete control over the ball and can manipulate it in any way. Using a variety of no-spin, topspin, backspin, and any amount of sidespin serves is critical to confusing opponents and keeping them “guessing” the serve type and not being able to “judge” it. The most effective way of doing this is to try and show the opposite direction of the actual paddle movement.

Serves can also be manipulated in regard to placement on the opponent’s side of the table. Long serves are serves that if given the chance would second bounce beyond the end of the table, while short serves would second bounce on the table. The placement of the ball can be in the center of the table or down the long channel, which refers to the forehand and backhand sides of the opponent. Placement strategies are important and specific to the opponents’ strengths and weaknesses. Short serves are often a good strategy against more defensive players while serves down the channel to the backhand are wise when playing an opponent with a weaker backhand stroke.

3. FOREHAND SMASH & LOOP SHOTS

The forehand smash and loop shots are two of the most dynamic and aggressive strokes in the game of table tennis and next to the serve they are likely the most commonly played strokes by experts. For this reason alone, it is important to discuss the mechanics of these two similar strokes. The forehand loop shot is a heavy topspin shot executed by a long sweeping upward stroke and can be used as a rallying stroke to later set up a smash or sometimes as a put away shot. The smash, on the other hand, is the fastest shot in table tennis and is almost impossible to return, reaching speeds around 60 mph and upwards of 100 mph (USATT, 2004). The forehand loop and smash can be broken down into five distinct phases including the preparatory movements, the backswing phase, force producing phase, critical instant and follow through.

Before a player can successfully execute any stroke in table tennis, the proper footwork and body positioning is necessary. This movement before the stroke begins makes up the preparatory phase. As mentioned earlier, table tennis is a reaction sport where a player must try to acquire as much information as possible from his or

her opponent before the opponent contacts the ball. This allows a player to accurately anticipate the opponent's shot and prepare earlier to return the ball. Recognizing the opponent's shot early allows more time to position the feet and body in a position ideal to return the ball and create a chance to score a point. Before preparing to hit the forehand loop or smash shots in particular, the trunk should already be flexed forward into a relaxed position that will later help to facilitate trunk rotation. Then, the feet should be positioned with the right foot further away from the end of the table (for right handed player), and the left foot slightly forward creating an open angle to the end of the table of



Figure 3.1: Proper foot placement and backswing position for forehand loop. Feet are positioned at ~45-degree angle to end of table. Right foot is open to almost parallel to the end of the table.

about 45-degrees. The right foot should be planted almost parallel to the end of the table and far enough back so that a wide base of support is achieved and the player is in a balanced position that will later allow for a transfer of weight onto the back foot (Figure



D

3.1). Once in this position, the stroke can begin.

During the backswing, the right hip is internally rotated while the trunk rotates back towards the right leg. The shoulders should now line up perpendicular to the end of the table. Simultaneously, the trunk is flexed laterally to the right, dropping the

shoulder of the striking arm and shifting the weight over the right foot. The unweighting of the front leg, shifting the weight back away from the table is a critical aspect of the

A

B

C

forehand loop and smash (Figure 3.1)

Figure 3.2. Force producing phase of the forehand loop.

reaction forces of national level and junior level Australian table tennis players. He found that the timing and unweighting of the body, when related to the timing of impact with the ball, was an important biomechanical variable demonstrated by highly skilled competitors. Also occurring at the same time, the arm is kept close to the body, not fully extended and maintains a relaxed position with slight elbow flexion so that the paddle lies

in front of the body and around knee height. It is important to remember that this position is the ideal and cannot always be attained during competition. The earlier an athlete can recognize the opponent's shot, the more likely it is that this backswing position can be attained. If time does not permit, these movements may have to be abbreviated in order to ensure that the critical instant (contact) does not occur too late. However, the quality (length, direction) of the backswing predicts how effective the force-producing phase will be.

The force producing phase of the forehand loop and smash shots is initiated by a forceful extension of the right leg, shifting the center of gravity upward and forward in the same direction that the ball will travel. At the same time, the trunk begins to uncoil and the right hip undergoes forceful external rotation bringing the shoulders into a position parallel to the end of the table, as shown in Figure 3.2A. This forceful rotation of the hips and trunk places the arm in a position left behind the body. The arm extends at the elbow, the wrist deviates towards the ulna (loaded position) (towards the little finger side of the hand), and the horizontal adductors of the arm are placed on a stretch that will elicit a more powerful concentric contraction. This action of stretching the muscles that are about to contract is known as the stretch shortening cycle or the stretch reflex. Once rotation of the torso is completed, any angular momentum that was generated in the upper body can be transferred to the distal segments of the striking arm, the lower arm and hand.

Angular momentum is equal to the moment of inertia of the body times its angular velocity. Therefore, if some of the momentum of the much heavier torso is transferred to the striking arm, the arm will be able to rotate with a very high angular velocity. A study by Neal (1991) examining the mechanics of the forehand loop and smash shots in table tennis suggests that the timing of the upper limb segments would be

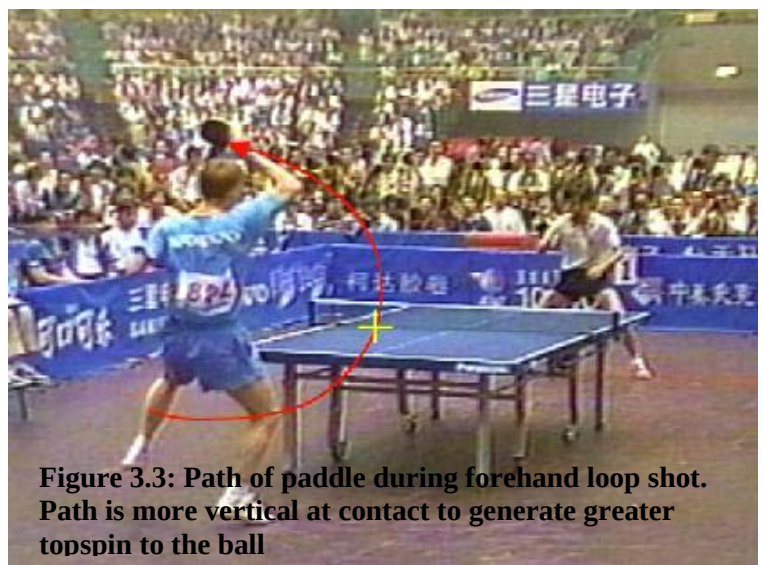


Figure 3.3: Path of paddle during forehand loop shot. Path is more vertical at contact to generate greater topspin to the ball

consistent with the summation of speed principle. This principle suggests that the contribution of the arm segment would precede the forearm and the hand, while these two segments are also timed in such a way that the proximal one contributes to the distal one. The study showed the hand to have the greatest peak velocity, followed by the forearm and then the upper arm. This pattern was seen in both the smash and loop shots, with the loop shot a scaled down version of the smash in regards to magnitude. However, the summation of speed principle suggests that the peak velocity of the proximal segment should be reached just prior to that of the more distal segment and this was not seen in the study. Neal (1991) found that all three segments peaked simultaneously at the instant of impact. Therefore, there is some doubt as to whether or not the speed principle holds true in the case of high speed table tennis shots.

This is the point in the two strokes where the loop and smash strokes begin to differ biomechanically from one another, while until now they have been very similar. The main focus of the loop is to apply a large amount of topspin to the ball and therefore, the path of both the center of gravity and the paddle is much more vertical and less horizontal (Figure 3.3). Contrary to this, the smash focuses more on power than on topspin, and therefore, the path is much more horizontal.



Figure 3.4. Forehand smash of top Chinese player.

Neal (1991) reported the smash shot of several Chinese players to have a large decrease in the vertical velocity component compared to the loop shot, and an increase in horizontal velocity. The vertical velocity of the loop shot at contact was approximately 8 m/s and decreased in the smash to around 5 m/s. Horizontal velocity on the other hand increased from just below 6 m/s in the loop to nearly 12 m/s in the smash. These measurements give a good indication of the differing path that the paddle follows when performing these two strokes. Neal (1991) calculated the ratio of horizontal to vertical velocity to be 2.2 in the smash and 0.6 in the loop. He suggests that a ratio of less than one is required to produce balls with a high rate of top spin (i.e. spin rates greater than 50 revs/sec).

4. Backhand Stroke

The backhand stroke in table tennis is used for shots aimed at the middle of the body or to the non-racquet side of the body. The ball is struck with the back of the racquet, or the dorsal side of the hand. The player uses a short backswing to bring the racquet into the front of the body, and a short forward swing of the racquet to propel the ball across the net.

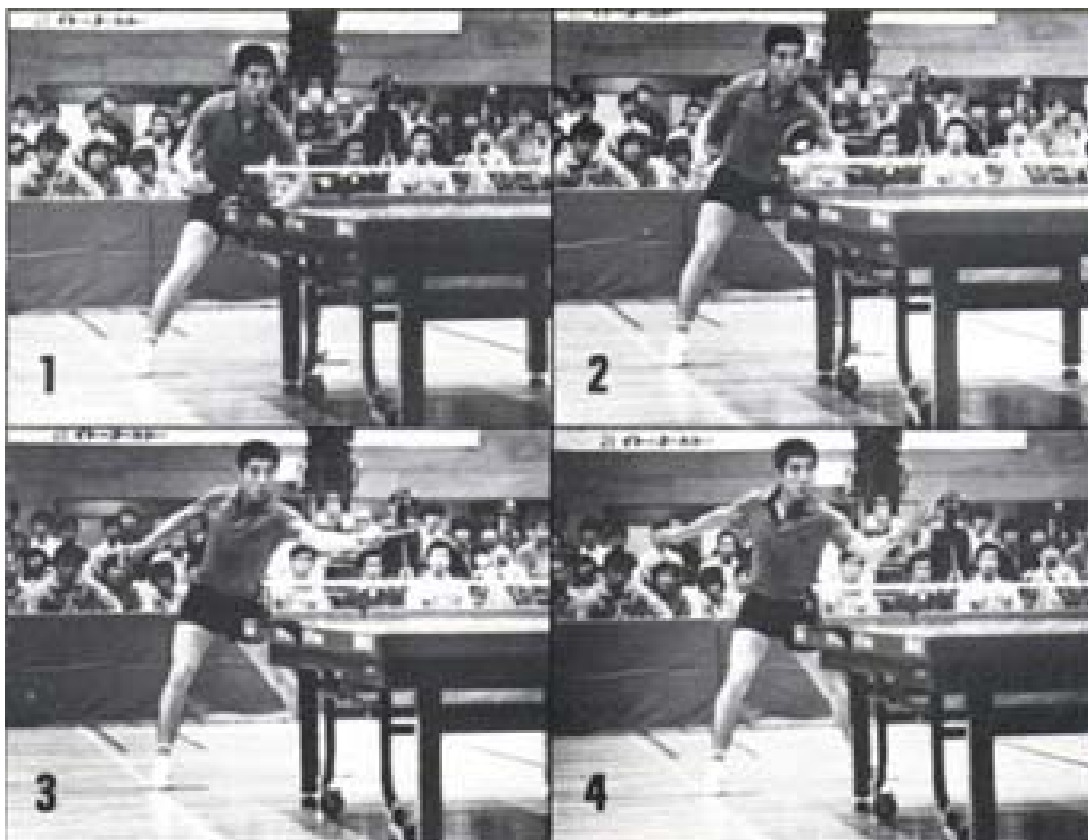


Figure 4.1. Phases of the backhand stroke from ready position to follow through [Robbins, 2009 #33].



Figure 4.2. Ready position in the backhand stroke.

The backhand drive in table tennis is performed with the dorsal side of the racquet, so the back of the hand is facing the direction of the stroke. The player remains facing the table with trunk and shoulders square throughout the backhand shot, since there is not enough time to perform a full trunk and shoulder rotation prior to the hit. The ball is always hit from directly in front of the body, and contact is made with the ball in front of the trunk. The feet are greater than shoulder width apart, the hips and knees are flexed and the trunk is flexed forward. The non racquet foot is slightly in advance of the foot on the racquet side, as this position favours a greater backward and forward movement of the racquet shoulder during the stroke.

During the backswing the racquet is drawn back toward the chest with the back of the hand squarely facing forward. The shoulder is abducted, flexed and medially rotated, the elbow is flexed to 90°, the lower arm is pronated and the wrist is flexed and adducted. The upper arm is first rotated internally and then rotated externally towards

impact in the backhand (Iino, More, & Kojima, 2008). To start the stroke move toward the ball, the elbow is extended, the shoulder is externally rotated and abducted and the wrist is extended and abducted (Figure 4.3). In the forward swing, the elbow is extended, the forearm supinated, and the wrist dorsiflexed (extended) toward impact (Iino et al., 2008). At contact the shoulder is in mid lateral rotation and abduction, the elbow is partially extended, the lower arm is semi supinated and the palm and the racquet are tilted slightly forward toward the ball. Iino (2008) concluded that upper arm lateral rotation was the largest contributor to racquet upward velocity at impact, assisted by shoulder abduction and flexion and elbow extension. The mean ball speeds for a skilled backhand drive were reported to be 20.9 m/s in returning a topspin shot, and 18.9 m/s in returning a backspin shot (Iino et al., 2008).

Following ball contact, the arm has turned completely over so that the palm is now facing the ceiling along with the racquet face (Figure 4.1-4). The shoulder is maximally laterally rotated and abducted to 90°, the elbow is fully extended, the lower arm is supinated with the anterior surface facing the ceiling (Figure 4.3). The hand is in a palm up (fully supinated) position with the palm facing the ceiling. This position represents the end points of the range of motion for the shoulder lateral rotation, supination and wrist abduction and extension that has just occurred.



Figure 4.3. In this topspin backhand the racquet is tilted forward at contact and the palm is facing the ceiling.

CONCLUSION

Table tennis is a sport that depends on finely crafted movements that occur very quickly and a precise execution of shots. It is a reaction sport that should be appreciated for the mental and physical prowess necessary to compete at a high level. Time is a luxury not available to elite table tennis competitors. They must rely on accurate anticipation of their opponent's stroke, constant alertness, reacting to the sound of the ball, and precise stroke biomechanics that allow them to select and execute the motor pattern that provides the best opportunity to win the rally. When training at a high level, table tennis coaches and athletes must consider the concepts of reaction time, spin on balls, and stroke biomechanics. A clear understanding of these principles during training will help the athlete to continue to improve and excel at the sport.

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