

## Research Article

### Tennis Forehand Stroke Action of Biological Mechanics Analysis

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**Abstract:** Forehand technique is the basic tennis technology, the highest utilization rate technology, but also the most lethal technology and one of the magic weapons of a tennis match. Grasp the qualitative and quantitative methods combined, the combination of video, movie, analytical and computer technology, combining the principles of the movement mechanics and mathematical statistics. Based on the biological mechanics principle and according to the latest research results of the element analysis and logic analysis, analysis of forehand stroke technical movement, which make us more subtle and correct understand forehand technique and eventually be able to provide a scientific theoretical guidance and practical reference for tennis teaching and training and make a small contribution to perfect tennis skills and innovation.

**Keywords:** Biological mechanics, forehand stroke, rotational moment, tennis

#### INTRODUCTION

From the Chinese tennis research current situation, tennis scientific research mainly can be divided into three categories: The first kind is by means of high speed video, in the process of hitting the links and the equipment movement data analysis, these study stroke process technical details. On the one hand, tennis ball experts can test a variety of don't understand the process of stroke and at the same time also found some ignored technical details in shot process; the second type is establish the model of sports biomechanics of sports action. By a large number of world high level technical movements of tennis players, to find their common ground, as the technical characteristics of the standard and for differences between the various players, through bio-mechanics theory analysis of its advantages and disadvantages and to find parts of Chinese athletes; The third kind is from aspect of the anatomic analysis of sports in the forced changes of muscle or muscle group, relatively little research in this area. But from another point of view, these research in this sermon form, largely confined to the technical statistics, experience, lack of pertinence and effectiveness (Wilson *et al.*, 1991). But in other domestic sports research, has through the technical statistics, experience, picture analysis gradually developed for qualitative and quantitative, video, video analysis and computer technology, combining movement mechanics and mathematical statistics and so on many kinds of research methods combining comprehensive use Bahamonde and Knudson (2003).

In recent years the research mainly focuses on the forehand stroke process upper limbs and trunk biomechanical analysis (Pluim and Safran, 2004). Although it was recognized long ago to the knee joint movement in the importance of forehand, but so far, for scientific research on lower limb movement in tennis remains very low. This research combines grasp the qualitative and quantitative method unifies, video and combines with video analysis and computer technology, combining movement mechanics and mathematical statistics, based on the principle of combining biological mechanics principle and according to the latest research results of the element analysis and logic analysis, with emphasis on the forehand of action research (Guo, 2006). For tennis teaching and training to provide scientific theoretical guidance and practical reference for tennis technology development contribution the meager strength.

#### BEFORE HITTING ACTION ANALYSIS

**Grip:** Hold the shot and the variability hitting have connection with the in-game adjustments. Half western style and western style forehand grip is now the most widely used grip. Note that, with the western style grip will increase accelerated swing elbow values pressure, increase the possibility of tennis elbow (Groppel, 1995). Relaxed grip batting-friendly rhythm and fluency, conducive to speed up head; But hold racket is also good, can prevent stroke point off center and the formation of rotational torque (rotational moment is when the ball impact and the ball away from the center

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of the racket distance vector product). Grip force itself to bounce the ball speed does not have apparent effect.

**Positioning:** At present most coaches and some tennis teaching experts' advocate in the open position, think that this stance modes can facilitate faster return shot after shot. Former US President tournaments and Porter points out, open stance hit in the face of the reaction force of the lower limbs is bigger, but also conducive to the rotation of the body, produce greater hitting power. But there are also research thinks, the lower half motor coordination power chain is concerned, open stance is not the best choice.

Bahamonde and Knudson (2003) the experimental results show that vertical stance forehand stroke from shoulder internal rotation moment and wrist bend torque peak significantly greater than the open stance (Andrew, 1997).

**Starting:** Tennis movement of the body to be in a dynamic balance in all shot action in the head and upper body must be stable. In preparation for the position to keep knees, lower the center of gravity, the split step. By a certain role in the former, the human body has been in a static or motion state, the inertia become human change that the biggest obstacle of state.

In a lawn tennis, every 2.5 sec have an average of 3.09 shots. This means that players average only 1.2 sec time to move to the right position and choose appropriate shot way to complete a shot. Deal with large Angle to the ball, widely adopted retrenchment step driving pace, in starting, the right to close up your left foot, so that we can quickly turn your center of gravity on bearing surface beyond, destroy the original balance, make use of the ground reaction force produced by the body, to provide explosive power.

**The racket process:** Turning the shoulder and back the racket, the racket trajectory is to position for shoulder clap, then down to the waist again by the upward swing. Consistent action look on the side like a bat painted "c",

so called c-type, its purpose is to let the racket from the time they have high, began to accelerate the racket, part of the potential energy into kinetic energy The knee bend, keep from low to high moving action, all the set point are in the state of complete. This way of the racket has been recognized by the most people. The racket process, appropriate increase muscle initial length, make muscle contraction produce tension also will also increase, so as to increase the power of the ball.

**SHOT PROCESS**

**Before hitting the paddle to accelerate power sources:** In tennis sports the force produce began from the knee joint and then pass up. Power comes from the ground reaction force. Studies have shown that in vertical position forehand stroke process, the initial position and range of activity directly affect the knee joint work; through the motor coordination chain indirectly affects racquet speed.

Although it was recognized long ago to the knee joint movement in the importance of forehand, but scientific study of lower extremity movement in tennis so far remains small.

In stroke process, shoulder muscles play out in great force, which accounts for a high proportion of its biggest power (Fig. 1). Shoulder movement for hit racket provides 15%~25% of the forward and upward velocity. The upper arm of the internal rotation to hit the ball respectively clap head provides 42%~44% of forward and upward velocity (Guo, 2006). Elliott also points out that in the upper arm stroke action before and after, there are obvious internal rotation movement, this movement is produce racquet speed (close to 30%~40%) of necessary aspects. The level of the upper arm adduction for racquet head provides 20% forward and upward velocity (Pluim and Safran, 2004).

**Before hitting accelerated racket hair force mechanism:** Alexander confirmed that two pieces of

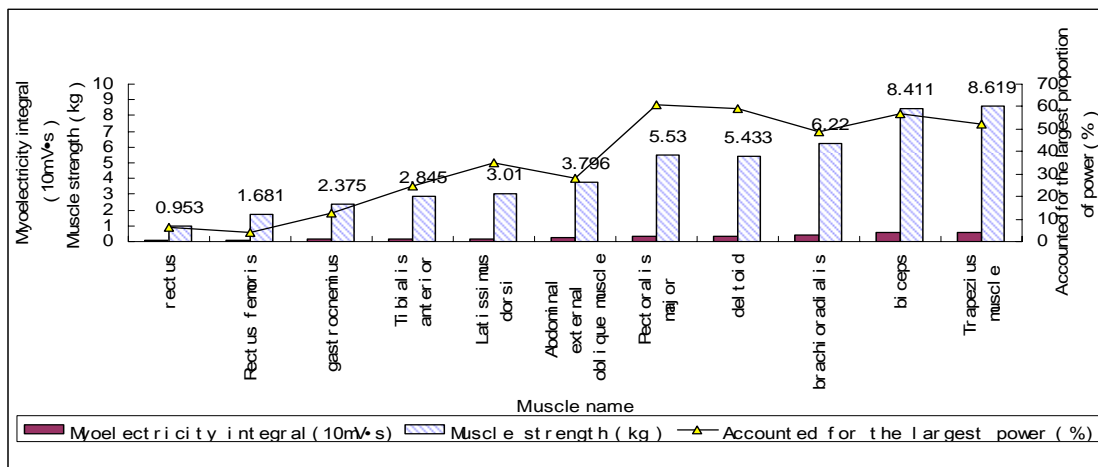


Fig. 1: Half-Western forehand, strength and muscle mass with phase integral value accounted for the largest proportion of power

muscle sequence shrinkage ratio and shrinkage of throwing distance farther, if two muscles between activity has a certain delay, can make the two muscles do total work is the largest, this is consistent with the order of muscle activity principle. In the three dimensional space inside, upper limbs every link speed change form from the upper arm to accelerate and brake in turn. But the upper limb joint activities sequence is not "shoulder, elbow, wrist", but "the shoulder, elbow, shoulder, wrist". But produce the sport order of the cause have connection with the control joint muscles moment size, muscle torque of joint movement form before muscle moment small movement form of a movement. This finding is of the traditional "joint order" theory added.

The sequence of the muscle activity can make Kinematic chain of various links speed additive, let end link finally achieve maximum speed; muscle activity order is not a simple equivalent whipped movement. Muscle electric experiment also confirmed the tennis forehand stroke action accord with muscle activity order principle. At the same time, the experiment also said in the whole stroke process, knee tribalism anterior muscle, shoulder trapezius muscle is always in the discharge state, this also shows that muscle activity order can not simply equal to flog movement. The calculation results show that each step of moment of momentum, ball movement of the upper limb the link obvious moment of momentum transfer. So the moment of momentum transfer is whipped action every link in the cause of the increasing speed.

**Before hitting the racquet acceleration process-two stroke way:**

**Bend arm stroke mode:** Bend arm stroke is the most widely used on the forehand (Fig. 2). Before drive, handle bottom facing to the ball. Stretch the shoulder to the left rear of the left side of the body, so that the pectoral is major muscle fully stretched, the initial length becomes longer, accompanied by stretch reflex, thus increasing the strength and continuity of the ball, as well as eliminating the left shoulder on the right shoulder horizontal adduction hindered ensure the maximum rotation of the body. On racket, its movement closer to the linear motion rather than circular motion, at this stage, the role of the racket has only increased the translational kinetic energy of the racket. Forearm and the longitudinal axis of the racket perpendicular to the (long axis) and also so that the racket around the body to the vertical axis of rotational inertia minimum, to facilitate the acceleration of the racket. Before hitting the upper arm clamping, elbow bend.

Moments before hitting racquet speed achieve maximum, the racquet face the dessert will touch the ball. The racket the motion state has become circular motion; hand to pull of the racket provides a racket the centripetal force. At this stage, the relaxation of the



Fig. 2: Equine arm stroke



Fig. 3: Straight arm stroke

forearm and wrist may reduce the resistance of antagonistic muscles generated, so that before the momentum of the body to produce the greatest degree of transfer to a racket.

Straight arm stroke mode: Straight arm stroke way technical action and bend arm shot are similar (Fig. 3), Difference is that elbows stretched (with Roger Federer's forehand attack the ball straight arm as an example). Research shows that, in Federer forehand touch a moment, racquet head (top) speed up to 130 km/h. Use the straight arm stroke can hit speeds of 160 km/h.

Seen by the theoretical mechanics, angular momentum  $J$  equal to the moment of inertia  $I$  ( $I = \sum m_i \cdot r_i^2$ ) calar product with the angular velocity  $\omega$ . At the same time, the definition is turning radius  $r$  and momentum of mv vector product. So, get the following relations: ( $J = I \cdot \omega = r \times mv$ ). So, whether the arm elongation, racket and arm rotating radius increase will cause the increase of the rotational inertia and influence of the angular velocity and the rotation of the body can affect racquet speed?

Scholars believe that most of the mass of the body in the lower extremities, the arm mass is smaller, so the rotational inertia by elongation arm increase amount is not large compared with the entire body of the moment of inertia  $\hat{I}$  ( $\hat{I} = I = \sum m_i \cdot r_i^2$ ). Linear speed ratio obtained lost the angular velocity of the impact on the batting to be more and more important.

Observed the ball when he has vacated is no longer subject to the forces on the ground, the total moment of momentum of the whole (+racket) system.  $J = I \cdot \omega = r \times mv$  can know that the racket angular velocity and speed are all reduced.

In fact, the straight arm stroke may actually improve the racquet head speed; we can not only solve the above

problem analysis shot time. Straight arm stroke way in the process of swing (from the racket to hit the end moment), are tend to be straight arm state.

- Straight arm hit and the body left bend arm of the moment of inertia is small, easy to turn ( $\tau = I \cdot \beta$ , Rotational torque is equal to the mom). Before hitting the ball, left shoulder (non-held shoot arm side) extent to the left rear, makes the pectoral is major muscle, right biceps muscle fully stretched, initial length of the variable length, muscle contraction generated the tension  $F$  increases.
- In a certain rotational angle  $\theta$ , arm hitting the angular velocity  $\omega$  is actually slightly smaller than the bent arm, which also caused the arm t a longer duration of action of the racket, from the momentum theorem  $Ft = \Delta mv$  can be inferred arm hit the ball the way you can make a racket greater momentum.
- Human in the racket accelerated the process of the work done by the racket  $W = F \cdot l$ . The acceleration of the racket to distance  $l$  (approximation for arc length  $l = \theta \cdot r$ ) Equal to the product of the angle and the turning radius  $\theta$  of the arm around the longitudinal axis of the body turned, so acceleration distance is longer. When straight arm stroke, accelerate the process of the body of the racket in the study done is the most, the kinetic energy theorem shows the kinetic energy of the racket is more bigger.

Straight arm stroke is gradually recognized by more and more people, Tournaments in the United States (USPTA) video tutorial, but also in favor of the straight arm forehand way. But straight arm stroke after all is not perfect, active tennis player of equine arm stroke is still dominant, Feeder himself often use equine arm stroke way.

**Touch ball time racket ball role distance:** The racket touch time variation is very small, only 3~6 ms. The world famous tennis coach Vic Breton research a high-speed camera photographed image, found that pat and ball contact is very short and the racquet head never roll a ball. However, since the racket technology advances in the past decades and forehand improved technology, particularly the forehand spin technology advances, the ball is likely to increase to a certain extent. Jia Jinchun think that when stroke, speed up if touch the ball with the racket speed to active impact to the ball, has the racket to send the ball for a period of time and process. Now, the design makes the tennis racket ball racket string bed net bigger, increase the eccentric moment strengthen ball rotation, at the same time, because the ball chord of the bed deformation increases, the ball will make for a longer time (about 0.4 millisecond extension). In addition, the bottom line type of player is the hands spin the ball, hitting point is not center of

racket dessert, but the batting point upper (instant hit racket is parallel to the longitudinal axis of both sides, respectively, while the racquet vertical axis level, as the upper and lower borders), racket vertical chord wear since the frame number 7 for the best. At the same time, the ball to hit the racket but did not produce a strong flip effect. This shows that the ball with the racket face contact happened after relative displacement, not the point contact. The author support shot rotation mainly from hit force line not through the globe and produce the eccentricity of the moment, but the above phenomenon do show that the ball in the string bed have relative displacement and today's topspin technology increased in the process of ball racket to the ball to do work.

## CONCLUSION

During the shooting, the big muscles hair force with small muscles control and cooperate with each other, not only rely on the arm strength and to use the whole body coordination force to obtain the biggest power. Motor coordination chain is the basis of the best skills to be effective play, it can cause the body to generate maximum explosive power, enhanced ball control capacity, delay fatigue and injury prevention.

Relative straight arm shot down, arm stroke has better stability, racket and swing time is shorter, so that players have sufficient time to prepare, But also for hitting times, strength, the rotation of the body and the requirements of coordination is relatively low, should be the only choice for amateur tennis player.

Increase the batting strength, increased duration of action and role of shoot the ball distance, this possibility can not be ruled out in order to improve the ability to control of the ball. In the positive hand rotary small slash technology, through the above method changes the ball flight path phenomenon seems to have reflected.

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