Sports Biomechanics Analysis of the Backhand Chop in Table Tennis

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Abstract
With the development of modern science and technology level, the research of sports biomechanics is also in depth, and the scope of its application is also expanding. In recent years, the reform of table tennis rules and system, how to enhance the professional technology of the table tennis athletes, and how to apply the sports biomechanics into the actual operation of the table tennis have been the focuses of research in the relevant institutions at home and abroad. Based on this, starting with the application of sports biology, the research of improving the effect of table tennis training by biomechanical instrument was done. With the professional table tennis players as the experimental objects, high-speed video recording analysis method was used to obtain sports biomechanics parameters of the backhand chop action, and the motion parameters of hip and knee and ankle, shoulder, elbow and wrist joints in the process of chop action were studied. In addition, the velocity, angle and angular velocity were studied and analyzed, and the relevant theoretical basis was obtained. It is proved by practice that the sports biomechanics analysis of backhand chop in table tennis plays a crucial role in providing the motion analysis, technical data for the athletes and coaches.

Keywords: Table tennis, backhand chop, sports biology, mechanics analysis.

Introduction

Nowadays, the combination of sports and science and technology is more and more closely, and new experimental methods and theoretical analysis have also constantly appeared in the research field of physical education, which requires us to have to look at things from the perspective of development, using advanced equipment to study on the basis of the results of previous studies. The research methods of sports biomechanics on table tennis can be broadly divided into two categories: one method is the use of mechanical theory for the study, and the other is through the experiment to study. To combine the two methods, in order to apply the sports biomechanics in practice, and the domestic scholars have carried out the relevant research.

Iino Y and others summarized the application status of sports biomechanics in table tennis movement analysis through the done the contraction and relaxation of muscle strictly in accordance with the order of time and space[9]. test methods for table tennis technical movements and movement analysis. At the same time, they discussed feasibility and necessity of the biomechanical testing methods in table tennis technical analysis[1]. For sports biomechanics studies of table tennis, Ghazal M and others mainly done the video segment timing and statistical techniques at the scene of the table tennis competition, and made technical monitoring and analysis on the movements of table tennis[2]. Mori T and others studied the gravity transfer of the table tennis and obtained that in the racket stage athlete body slightly transferred to the left, shifted the gravity to the left; In the process of swinging the ball racket to racket touching ball stage, the body center of gravity from the left foot gradually moved to the right foot; With the potential of the swinging racket stage, the body quickly restored to the ready position[3]. Raab M and others studied the technical movement of table tennis, which showed that every time the player shot a ball, he should quickly adjust the center of gravity, in order to get ready for fighting back the next shot, and restore the body as far as possible close to the ready position. If the body center of gravity, forearm and racket stay on the move for a long time, the next action of the convergence would be very negative, which would affect the outcome of the game[4]. Munivrana G and others used the biological movement theory to study force skills of backhand chop in table tennis, it is concluded that the order of chopping force was from the ankle to the knee to waist and abdomen to the upper part of the body until the wrist[5].

In addition, table tennis is a highly focused project with fast speed and many changes. Athletes need to make corresponding action reaction in a very short period of time, and in the process of the shot, athletes' eyes must tightly keep a close watch on the opponent and the ball. To judge whether the ball is accurate is a prerequisite for hitting[6]. To lower the center of gravity of the body through the knees can narrow the field of view. The relative concentration of vision can improve the ability to judge the ball. The angular velocity of the knee joint at the moment of hitting reaches the maximum, and into the potential swing stage, the curve decreases rapidly[7]. Glynn J and others studied the chop technique of table tennis, and they believed that in the process of backhand chop, players only needed to consider related content of hit rate, without the need to consider the effect of the ball's impulse force on the racket and the wrist of athletes[8]. By conducting on-site actual operation analysis of table tennis players, Kentel B and others thought that table tennis was a demanding action and coordination of movement and it needed the correct coordination of time and space which required that athletes

Based on the combination of theory with reality, the backhand action is researched in this paper, and the joints' motion parameters of backhand chop action are obtained, which can help physical education teachers and athletes in colleges and universities get a more in-depth understanding of backhand chop action, also can help teachers for correct guidance. In the teaching practice, when students with basis of one technology are in practice another technique, it can help them understand where we can share the resources, where must be treated differently, and promote the rapid development of sports teaching practice.

Application of sports biomechanics

Application of sports biomechanics in sports: Research on sports by sports biomechanics is using the movement simulation way to conduct the simulation research on the human body movement[10]. The research process can be divided into five steps. The first is to establish an appropriate objective function according to o the characteristics of the movement. The second is to choose the model to determine the degree of freedom of the rigid body. The third is to establish a dynamic model. The fourth is to solve the known data which are the actual measurement. The fifth is to study and analyze the results, and obtain the motion regularity. The last step is particularly important, which is the key of converting mathematical rules into sports language, and can provide effective guidance for athletic technical movements. Through the above research, we can study many problems in sports. Using sports biology study to table tennis can analyze trajectory of wrist, elbow, shoulder, lumbar and cervical vertebra joint and study force's quantitative analysis in the process of hitting, so as to reduce and prevent athlete's injury.

Biomechanical instrument commonly used: The main test equipment of sports biomechanics have been widely used in sports, such as kinematic parameters-high-speed cameras, high-speed video, kinetic parameters-3D dynamometer, muscle working characteristic-EMG instrument, anthropometric parameters-calculation model and simulated imitation. However, these biomechanical instruments have not been widely used in table tennis sport. Three-dimensional force measuring platform can reflect the reaction force of the ground to the human body.

The strength of a player's ball is achieved through the interaction with the ground. Putting pressure testing insoles in shoes of table tennis players can obtain the distribution of pressure on the sole in the moving process of the athletes, which can provide effective parameters for the athletic shoes design. EMG can track and record the intensity and time of muscle activity in the movement, and find the predominant muscles involved. In table tennis, using EMG for athletes can know that the muscle force in the completion of a technical movement, and provide effective reference data for the training.

The use of biomechanics for table tennis training: Through the test of biomechanics, we can draw data of movement, amplitude, strength, direction, trajectory of some technical action, but for these abstract data, athletes and coaches cannot master effectively in training. If the abstract data are through processing equipment converted into sound and light signal, to give direct action tips for athletes, and make it clear that whether action at that time achieves the requirements of the scope. According to the signal received, athletes immediately make the corresponding response, so the adjustment of amplitude, the intensity and the speed of the action is easier. The use of sports biomechanics to study the table tennis movement can make us have a more profound understanding of the law of table tennis through the multidimensional vision, and provides services for the practice of table tennis.

Biomechanical experiment on table tennis backhand

Experimental objects and devices: Experiment object: This paper selects professional table tennis players with the sport life of more than 8 years as the experimental object. Experiment equipment: A three dimensional DLT framework of Aijie; two sets SONY cameras with the same specifications; two camera professional lights; two notebook computers.

Experimental process: Video location is a tennis hall of the sports college, and the two camera special lightings are used to increase brightness. In order to obtain good image shooting effect, set serving placement region in order to make sure the athlete complete the shot action in shooting range, and set the table across and the third range of the field is effective placement area. (See Fig. 2) Table tennis: The high of A camera lens is 1.35m, the same high as that of B camera. The high of the origin point is 71cm, and the distance from the ground to the center of the framework is 89cm. The distance from the origin point to A camera is 8.4m, and that of B is 8.7m, the distance between A and B is 12.1m, and the main light axis of the two cameras is about 90°. 2.3 hit effect check level statistics

In order to make the players hit the ball initiatively, and make a full stroke, the other side of the ball is asked for the fast ball, and other players waiting for the shot will make evaluation on the action and the effect. In the analysis process, the APAS system is used to analyze the moving image to obtain the desired kinematic data. The analysis process total enables six modules of the APAs system, including image acquisition module, image shearing function module, digital image analysis module, data synthesis and transmission module, data smoothing function module and data display function module. The data obtained by the APAs system data display function is processed using EXCEL for kinematics data acquisition of backhand chop in table tennis, which can provide the basis for the later theory analysis[11].

Fig. 1: Sports biomechanical testing instruments used in sports

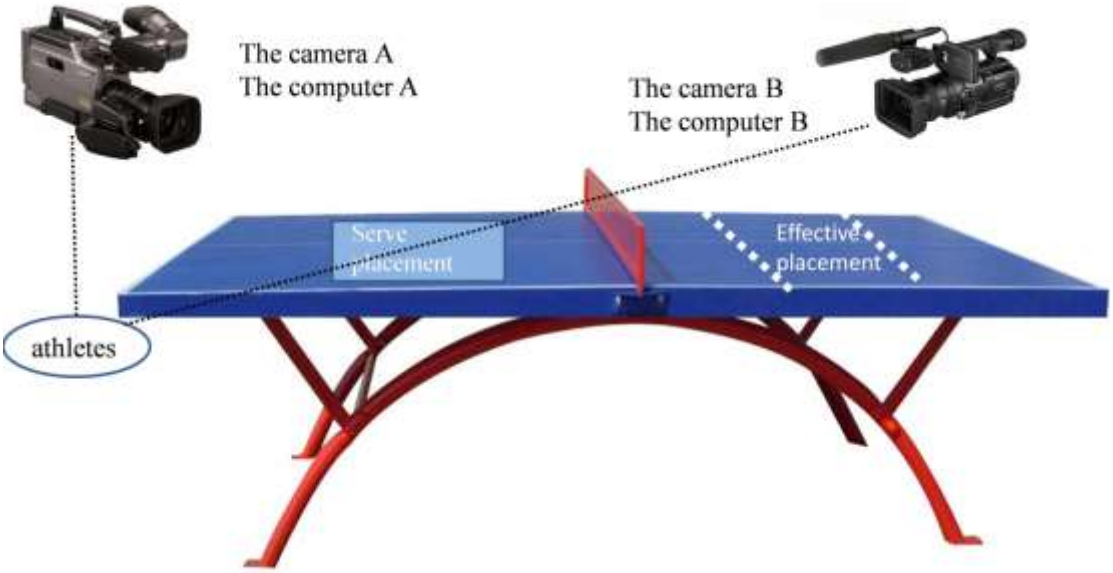

Fig. 2: Table tennis experiment site Settings

Related concepts and research content: Table tennis chop: Technical terms of table tennis. It is a technique of cutting a ball with a friction force of a racket. When hitting, racket is in the state of fadeaway, and be swinging from the top of the side of the body to forward and downward with a circular route, and touch the below middle part of the ball when it is lowering [12]. Backhand chop: Stand right foot slightly front, with the upper left, the center of gravity on left foot, and the hand that holds the racket is placed on the chest with relaxed natural bending. Along the way swing the racket to the upper left of the ball around the shoulder high, and shoot down. When the ball bounces, wave your hand which holds the racket from the upper left on the right bottom, with the racket face backward, accelerate the cutting force on the racket by the forearm and wrist, hit the below middle of the ball in the falling when the racket is on the chest left 30 cm place, and then swing to the below right [13]. And the coordination force of arm, waist, abdomen and legs is the focus and difficult.

Displacement: The straight-line distance of a particle from a position to the next position with a direction, which is called displacement, and the unit is "m". Speed: The speed value reflects the motion of a point relative to the ground, which is called the speed, and the unit is "m /s". Joint angle: The angle formed by the two parts of the human body is called joint angle, and the unit is "degree". Angular velocity: The speed of change in the angle is called the

angular velocity, and its unit is "degree/ second". Shoulder joint angle: The angle between right upper arm and trunk. Angle of elbow: The angle between right upper arm and right forearm. Wrist joint angle: The angle between right forearm and right hand. The angle of the hip joint: The angle between the right waist and the right thigh. Angle of the knee joint: The included angle between the right thigh and the right leg. Ankle joint angle: The angle between right leg and right foot [14]. The body's center of gravity: The action point of the gravitational force of all parts of the human body.

Analysis of the lower limb biomechanics of backhand chop in table tennis

The analysis of sports biomechanics of the hip joint: According to the principle of human body movement physiology, it is known that the force of man's whole movement begins at the waist and hip, so the waist hip is called "the engine of human body movement". After the hip force, it will upload to the upper arm, forearm, hand, leg, foot, and after the feet pedal to the ground, the ground gives a reaction force to the feet. And this force goes along the sequence of foot, leg, thigh and trunk, and it accelerates the conduction after the force with the normal transmission, namely the force through upper arm, forearm and transmitted to the hand, the two set together and action on the ball through the racket. Therefore, the waist hip strength increases, the strength of the transmission will be increased, thus showing the rapid movement and the increased power of the ball. As shown in Fig. 4: Hip velocity are in a rising trend in the racket stage, and in the stage of towards the ball swing to touch the ball racket, the body twists to the right to chop, the left forefoot medial pedal, and hip rotates to the right.

It can be seen from the hip joint angle curve that the hip angle is the smallest when athletes in the racket ball instant. In the whole process of backhand chop, trunk makes a small amplitude range of twist, and the change of hip joint angle is very small. In the racket stage, the angular velocity of hip joint shows a downward trend, rapidly rising in the stage of towards the ball swing to touch the ball racket, and then gradually decreases in the potential of swing stage. This shows that the technical movement of modern table tennis backhand chop pays attention to simplicity and efficiency.

Fig. 3: Table tennis backhand chop action figure

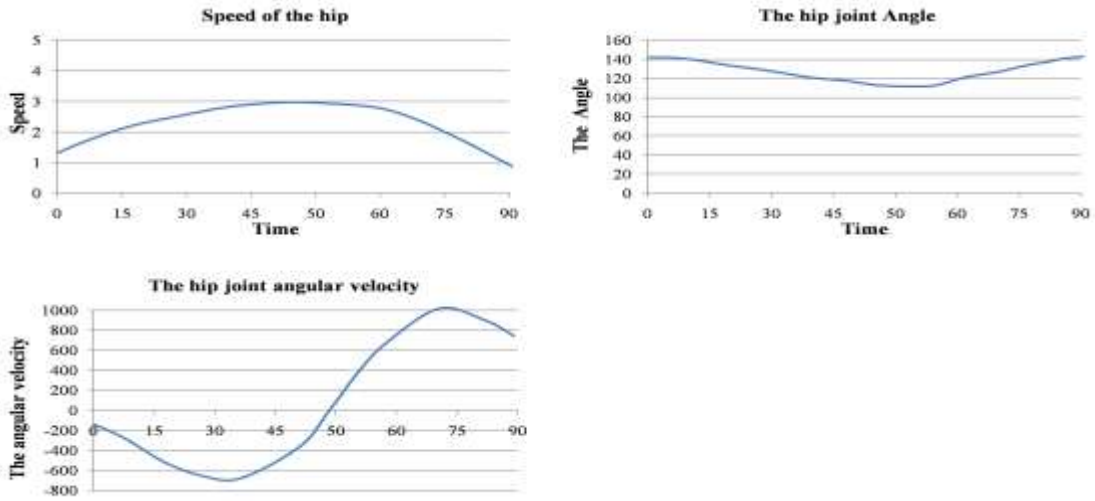

Fig. 4: Hip curve of each variable changes

Table 2
Comparison of different variables of knee joint

		Knee joint velocity	Knee angle	Knee joint angular velocity
Professional player	Maximum value	2.82	167.11	847.62
	minimum value	1.45	133.74	-481.26

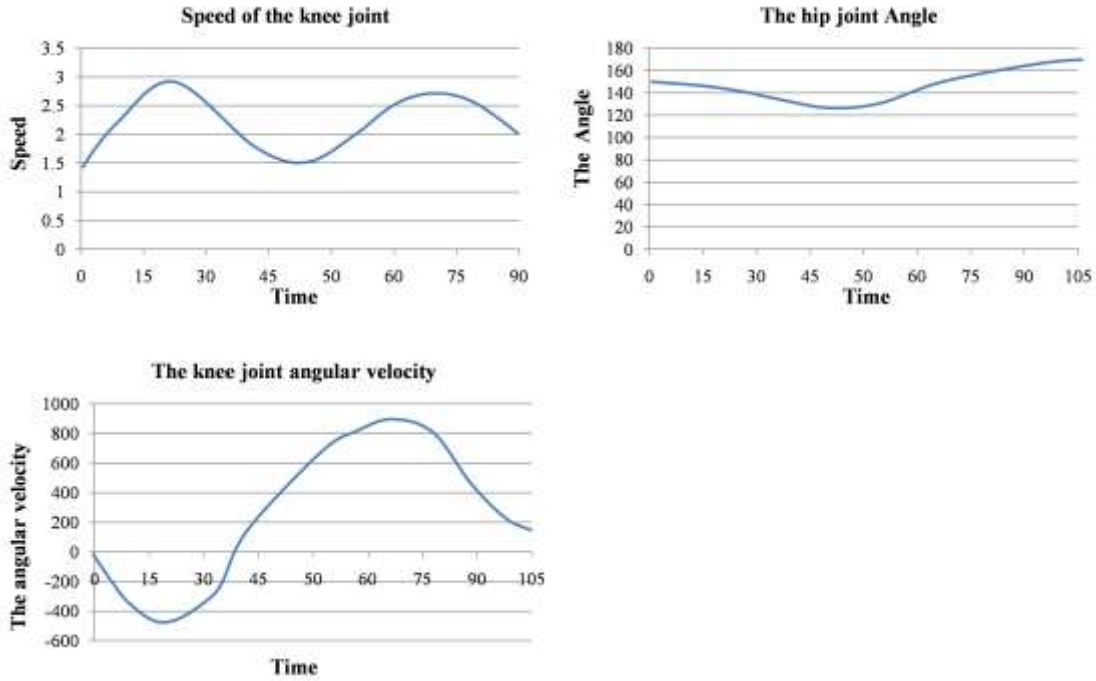

Fig. 5: The curve of the knee joint of each variable changes

The analysis of sports biomechanics of the knee joint: Knee joint is in the middle position of the hip and ankle joints in the joints of the lower extremities, which is the center of a connecting link between the preceding and the following, connecting the thigh and the lower leg, and is the main link of lower limb power transmission [15]. In the process of hitting, knees slightly bent, upper body slightly leaning forward, too big or too small knee joint angle has no effective tic effect. The size of knee angle and the stretching force of the lower limb are closely related, the angle of knee joint is relatively fixedly at around 140° in the racket stage, swing to touch the ball racket stage and with the potential of swing stage. In the moment of the ball hitting, the knee angle of the athlete has been reduced and the speed curve has been reduced. Because at this time to reduce the angle of the knee joint can reduce the body's center of gravity to hit the ball more robust, to reduce the speed of knee joint is to with friction time of the ball on the racket when upper limb increase the hitting, which is convenient for athletes to increase ball rotation force.

Knee angle is relatively fixed in the three stages without obvious change, indicating that the center of gravity has no obvious ups and downs in the process of hitting. Through knee to reduce body weight ball, the body will not rely solely on across the ankle muscles contraction to start the body and knees supporting reaction force will increase the force effect.

The analysis of sports biomechanics of the ankle joint: The human body depends on the contraction of the muscles of the ankle to start the body, and in order to obtain the ground reaction force, must make the muscle contraction contact the joint activities to give a force to the ground. Force conducts through the ankle joint, knee, hip and other links to the upper, and ultimately actions on the racket. In the transmission process of force, the ankle is the link closest to the supporting point, and is the end link of the lower extremity kinematic chain, the dorsal flexion of ankle joint can increase the effect of the supporting anti-force [16]. In the process of hitting, right leg slightly stretching, ankle joint angle maintains stable in three stages, and individual variation range is not more than 20°, and maintaining a relatively fixed knee angle also makes ankle angle relative to the fixed. Therefore, the speed, angle and angular velocity of the ankle joint are very similar to the knee joint. The values of velocity, angle and angular velocity are all lower than that of the knee joint. Positive buffer of ankle joint makes body weight decrease, and the stretching speed of the lower leg extensor muscles and lower limb extensor increase.

Through the comparison different variables curve of the knee joint in Fig.5 and that of the ankle joint in Fig.6, it is seen that the peak of the angular velocity of the ankle joint appears before that of the knee joint, and the curve motions of the two joints are very similar. Thus, the force process of

backhand chop in table tennis is a strict spatial and temporal sequence, and the cooperation is fast and accurate. Therefore, in the table tennis backhand chopping process, whether local joints and joints of the whole body are in coordination is related to the reasonable structure of the whole technology movement.

Analysis of the upper limb biomechanics of backhand chop in table tennis

The analysis of sports biomechanics of the shoulder joint: On the racket stage of backhand chop, arm of players phase natural bending, the racket is slightly high over the left shoulder and higher than the ball, which is helpful for friction ball forward and downward on the next stage. And on the swing racket stage, the arm waves forward and downward, and when the racket touches the ball, the forearm accelerates to extend out [17]. Shoulder joint changes from the adduction later to outreach slightly anteflexion, and in the hitting process, the concentric work is done mainly by the pectoralis major, latissimus dorsi and other shoulder muscles nearly fixed, and it completes the work under the nearly stationary conditions for muscle restraint. Shoulder joint's contribution to the upper limb strength is the largest in the upper limb movement, and it is the largest joint in the upper limb. The curve of each variable of the shoulder joint can be seen from Fig. 7. After the start of the ball movement, due to the momentum transfer from lower limb joints and the hip joint, the shoulder joint has a certain initial velocity, and the angle of the shoulder gradually increases with the lead shot. On the stage towards swing to touch the ball racket, shoulder joint angle gradually decreases, and makes the distance from center of gravity of the upper arm close to the shoulder joint, to overcome the smaller resistance moment. On the potential of swing stage and to the most distal, the shoulder joint angle increases slightly.

Velocity and angular velocity of the shoulder joint decrease rapidly on the stage towards swing to touch the ball racket, and when the racket touches the ball, they down to the lowest, which suggested that the shoulder joint first become the fulcrum in upper limb stroke. Because the muscle cross-sectional area of shoulder joint is far greater than that of the elbow and wrist joint, the movement speed of the shoulder joint suddenly brakes before the racket touching the ball, and the momentum of the upper arm is transferred[18].

The analysis of sports biomechanics of the elbow joint: The elbow is driven by the shoulder joint and the forearm. As shown in Fig.8, the elbow each variable curve shows that the speed change trend of elbow joint is similar with that of shoulder joint. And on the swing racket stage, the arm that holds the racket waves forward and downward, and when the racket touches the ball, the forearm accelerates to extend for chop [19]. Compared to the shoulder joint, the angle of elbow joint before and after the stroke has larger changes. And in the process of chop, in order to increase the hitting power and speed, bending the arm, elbow joint angle is at about 90°. When hitting, the elbow joint becomes from bending to stretching, with the increase of elbow angle. The contraction force of triceps and anconeus of elbow joint extensor is used, and the work centripetal is done by the fixed triceps and anconeus. Therefore, before hitting, the fixed angle of the elbow joint is easy to force the ball, and on the racket stage and the stage forwards swing to touch the ball racket, the elbow joint angle makes the center of gravity of the whole arm, including the upper arm and the forearm, close to the shoulder joint which is the waving fulcrum. Therefore, the resistance moment for this angle of the elbow in the process of hitting the ball to overcome is also small.

The bending angle of elbow joint in the hitting process not only plays the strength of shoulder extensor and using the shoulder joint as a fulcrum, based on the angular velocity that shoulder joint has, the elbow joint plays contraction force of elbow extensor muscles to make the forearm obtain greater angular velocity. Therefore, the angular velocity of the elbow joint of each stage is greater than that of the shoulder joint. The angular velocity of the elbow begins to drop rapidly before the racket touching the ball, which indicates that the elbow has already started to brake before the racket touches the ball, and the momentum is transferred to the next step.

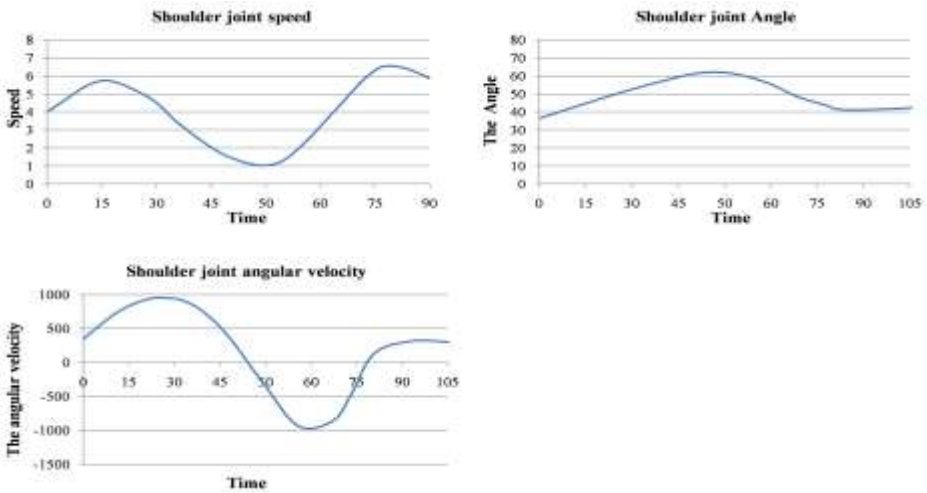

Fig. 7: The curve of the shoulder joint each variable changes

Table 4
Control table for each variable of shoulder joint

		Shoulder joint velocity	Shoulder angle	Angular velocity of shoulder joint
Professional player	Maximum value	7.54	58.79	875.75
	minimum value	0.98	35.01	-884.98

Table 5
Control table of the variables of elbow joint

		Elbow joint velocity	Elbow angle	Angular velocity of elbow
Professional player	Maximum value	10.02	137.88	2243.65
	minimum value	2.95	80.01	-612.58

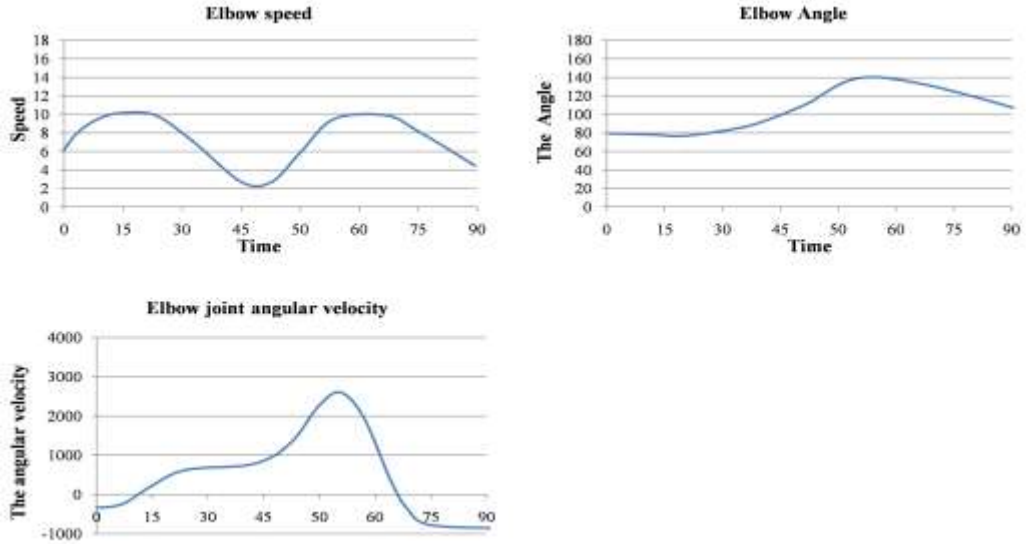

Fig. 8: Elbow each variable curve

Table 6
Control table of each variable of wrist

		Wrist joint velocity	Wrist joint angle	Wrist joint angular velocity
Professional player	Maximum value	14.99	173.84	3998.64
	minimum value	8.78	142.75	-823.38

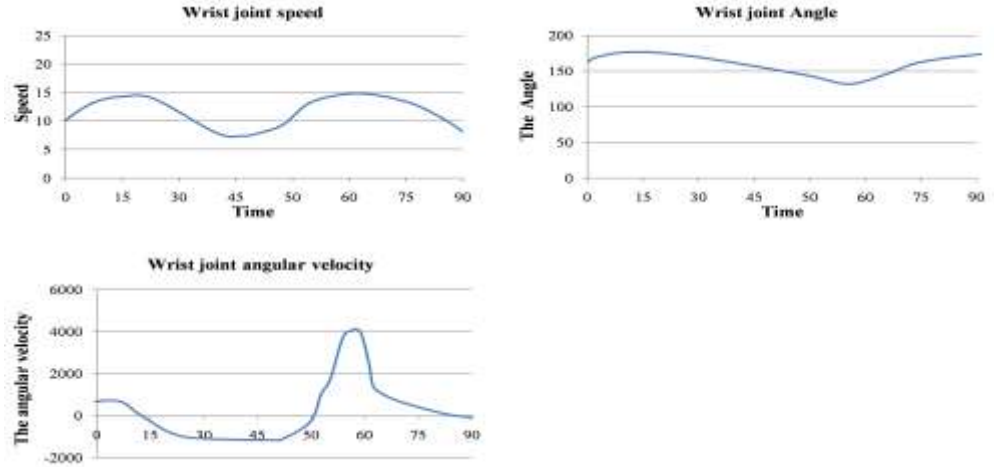

Fig. 9: The curve of the wrist joint each variable changes

The analysis of sports biomechanics of the wrist joint: Due to the medium ball velocity of the experimental design, players hit the ball time earlier, and in addition to the downward and forward friction ball movement, it should highlight the use of downward cutting action, and rapid shots are based on the forearm and wrist force. As is shown in Fig.9 with the curve of the wrist joint angle, the angle of the hand and forearm is smaller when the racket is closer touching the ball, and at the moment of racket touching the ball, wrist angle begins to increase. And at this time, flexor carpi ulnaris, ulnar extensor muscle of wrist and finger muscles control and regulate the concentric work. This racket radiocarpal joint produces a line speed, so when forearm and racket hit the ball, a certain angle exists so as to easy to play the wrist in an instant hit of adduction and abduction and flexion and extensor contraction force[20].

Table tennis backhand action is the complex and comprehensive action of the athletes' body, which is a synthesis motion of multiple pivots. Wrist joint angle velocity is composed of shoulder joint around the trunk, the elbow joint around the shoulder joint, wrist joint around the elbow joint, and based on the existing joint angular velocity of the fore joint, the contraction force of extensor is played, which makes the wrist joint get greater angular velocity on the stage forwards swing to touch the ball racket.

Therefore, compared with the shoulder, elbow, wrist joint angular velocity of respectively in Fig.7, Fig. 8 and Fig.9, it can be seen that the angular velocity value is gradually increased. Because the wrist uses the elbow as a fulcrum, elbow uses shoulder as a fulcrum, and on the basis of the angular velocity of the shoulder joint, the elbow joint has obtained a greater angular velocity by exerting the force of contraction of the extensor muscle group.

Conclusion

Table tennis is a worldwide movement, and China has been in a leading position in the field of table tennis. With the rapid development of modern table tennis technology, we must rely on the power of science and technology and means to more comprehensively and profoundly understand the rules of the table tennis technology. Therefore, it needs our comprehensive sports biomechanics research of table tennis. Taking chop skills for example, video tracking of the professional table tennis players chop action is conducted, and APAs system is used for image motion analysis, so as to obtain the velocity, angle, angular velocity and kinematic data of each joint of the upper and lower limbs and analyze the data. And action skills of the pace, force site, speed, strength and gravity center offset of table tennis chop, which can provide certain theoretical basis for the training of coaches and athletes. Practice has proved that the movement biomechanics analysis of table tennis backhand chop can effectively improve the table tennis athlete's technical skills and promote the development of China's table tennis career.

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