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The Effects of Scapular Stability Training on Serve Speed and Accuracy in College Tennis Players from the Perspective of the Kinetic Chain

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Abstract

Background and Aim: In the tennis serve, the scapula serves as the bony connection between the core, spine, and shoulder. It is the main fulcrum of the body's dynamic chain transmission and plays a very important role in the energy transfer process of the upper limb movement. The objective of this research was to study the effect of scapular stability training in the service kinetic chain on the speed and accuracy of the tennis serve.

Materials and Methods: 16 college tennis players from Guangzhou Polytechnic of Sports were randomly selected for this study as a sample group, and divided into an experimental group and a control group, with 8 students for each group (4 males and 4 females). The period of training was 8 weeks. After the tennis training class, only the experimental group will perform scapula stability training twice a week (Monday and Wednesday) for 60 minutes each time. This research used literature methods, expert interviews, experiments, and mathematical statistics to conduct experimental research and theoretical analysis on the effects of scapula stability training on the serving speed and accuracy of college tennis players

Results: The results showed that 8 weeks of scapula stability training had a significant effect on improving the stability of athletes' scapula. The scapula stability of the control group (6.81±1.09) and the scapula stability of the experimental group (9.45±1.33). Scapula stability training has a significant effect on the serving accuracy of college tennis players. The serving accuracy of the control group (30.38±5.34) and the serving accuracy of the experimental group (35.50±2.67). Scapula stability training has no significant effect on the serve speed of college tennis players. The serve speed of the control group (136.80±23.89) and the serve speed of the experimental group (122.12±35.71).

Conclusion: The results showed that scapular stability and serve accuracy in the experimental group were significantly higher than in the control group ($p < 0.05$). In terms of serving speed, there was no significant difference between the experimental group and the control group ($p>.05$). Within the experimental group, there were significant improvements in scapular stability, serve accuracy, and serve speed before and after the experiment ($p < 0.05$).

Keywords: Scapular Stability; Serve Accuracy; Serve Speed; College Tennis Player

Introduction

Scapulothoracic kinematics plays a key role in the normal function of the upper extremity since it affects shoulder stability, the integrity of the superior labrum, the dimension of Acromiohumeral space, the function of the rotator cuff and the motion of acromioclavicular and sternoclavicular joints (Postacchini and Carbone, 2013). The stability of the scapulothoracic wall joint relies on the action of the surrounding muscle groups. The scapula must maintain the dynamic stability of the articular fossa for effective glenohumeral joint motion to occur. When the scapular stabilizing muscles are weak or dysfunctional, the normal scapular position and function are altered.

In tennis, the serve is considered the most strenuous stroke (Roetert et al.,2020). According to Martin (2014), tennis serve is defined as a “sequence of motions referred to as a kinetic chain that begins with the lower limb action and is followed by the trunk and the upper limb”. During the different phases of the tennis serve, kinetic energy associated with the groundstroke and knee flexion is transferred to the trunk, which rotate and flex to transmit energy and velocity to the upper limb, the racket, and then the ball. It means that all the links of the chain may have an influence on the serve and that dysfunction of one of them may have an influence on the others and consequently on performance (Kibler & McMullen, 2003).

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Given the place of the scapula in the kinematic chain and the important activation of scapular stabilizers during tennis serve (Kibler et al.,2007), a link between scapular kinematics and tennis service performance should be considered. So, Recognizing the role of the scapula in upper extremity function is now a required component of upper extremity training design. All training must be integrated with scapular stabilization techniques to keep the scapula in a proper position, prevent impingement, and maintain the length-tension relationship of the muscle group.

There are numerous research results about functional training, strength training, and tennis serve training, but there is no relevant practical demonstration about the specific reasons for the change of tennis serve speed and accuracy with scapular stability as the independent variable. Starting from the relationship between scapular stability and tennis players' serve speed and accuracy, this thesis aims to reveal the role of scapular stability training in improving college tennis players' serve speed and accuracy through scapular stability training for college tennis players.

In this study, we designed scapular stability training tools for tennis serve based on the mechanisms of motor chain mechanism, joint-by-joint theory, and dynamic neuromuscular stabilization technique, and explored the effects and mechanisms of scapular joint stability training tools on the speed and accuracy of tennis serve.

Objectives

To study the effect of scapular stability training in the service kinetic chain on the speed and accuracy of the tennis serve.

Literature Review

1. Anatomic structure of scapula

1.1 Morphological characteristics of scapula

The scapula is a flat, triangular bone located posterolateral to the thorax of the second and seventh ribs. It is at an angle of 30 º to the thoracic coronal plane, slightly rotated to the midline at the upper end, and inclined to the sagittal plane (Laumann, 1987). The spina scapulae extend from the side to the acromion, and the acromion and the lateral end of the clavicle join at the acromioclavicular joint. The coracoclavicular ligament and muscle connection support the scapula and stabilize its connection with the chest. However, there is no bony connection with the axial bone, which makes the scapula have a large range of motion, including extension, contraction, lifting, sinking, and rotation (Nordin, et al., 2001).

1.2 Muscles at the scapula

Shoulder muscles can be regarded as layered distribution, and the outermost layer is composed of deltoid muscle and pectoralis major muscle. The deltoid muscle forms a normal round contour of the shoulder, which is triangular, including the front, middle, and rear heads. The excitation of different parts of the deltoid muscle can cause specific movements. The deltoid muscle starts from the lateral 1 / 3 of the clavicle, acromion, and scapular ridge, and terminates at the anterolateral side of the humerus. The main function of the anterior head of the deltoid is to bend and rotate the humerus, the main function of the middle head is to abduct the humerus, and the main function of the posterior head is to extend and rotate the humerus. The pectoralis major muscle is located in the front of the chest wall and has two heads. The clavicular bone starts from the clavicle, and the Sternocostal head starts from the sternum, Sternocostal stalk, and upper costal cartilage. The two heads meet at the sternoclavicular joint. The pectoralis major muscle stops at the internodal sulcus between the humeral nodes, and its function is to make the humerus adduction and internal rotation. In addition, the clavicular head also plays a role in flexing or lifting the humerus, while the Sternocostal head can extend the humerus. The pectoralis minor muscle is located in the deep part of the pectoralis major muscle and is one of the important fixed scapular muscles. The pterygoid subclavian muscle is located under the clavicle and assists in the movement of the clavicle. The tendon origin of the subclavian muscle starts from the anteromedial side of the first rib and ends below the medial end of the clavicle (Morrey, et al., 2004).

1.3 Stabilizing muscle of scapula

The scapula provides an anatomic connection between the trunk and upper limb. The movement of the scapula is completed by the muscle groups that fix the scapula, serratus anterior, trapezius, rhomboid,

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and elevator scapulae. The stability of the scapula depends on the action of the couple: that is, the muscles with opposite forces are used to provide stability and movement (Schepsis, 2006). Kuhn, et al believed that the muscles that provide stability to the scapula mainly include the rhomboid muscle, trapezius muscle, and serratus anterior muscle. The weak strength of these scapular stabilizing muscles will lead to shoulder brachial rhythm dysfunction, which will lead to or cause shoulder joint injury. Studies have found that 68% of rotator cuff problems and 100% of glenohumeral joint instability are associated with scapular dysfunction (Kuhn, et al. 1995).

2. Research on the kinematic chain

2.1 Joint chains in kinematic chains

Joint chains include two or more adjacent joints. According to different functions and structures, the joint chain is divided into a posture chain and a dynamic chain (Janda & Jull, 1987). When a good posture chain is used, the center of gravity of the body is evenly distributed at all joints, and the force is smooth, which determines the kinetic energy transfer efficiency between joints. Functional training of FMS to screen bad posture and assess the degree of imbalance is good proof. A power chain (Cook, et al., 2010) (Boyle, et al., 2012) is a chain structure in which the energy of muscle contraction is transmitted through joints. Therefore, the fluency of the power chain represents the ability of stable joints to maintain balance and the ability of flexible joints to produce force. Blackburn found that there are two basic forms of power chain work: open kinetic chain (OKC) and closed kinetic chain (CKC). Open chain movement emphasizes the flexibility, speed, and explosive force of the limbs, and the distal end of the limbs can move freely, such as various whipping movements. The activities of human upper limb joints are mainly open chain movement, so the flexibility of the upper limb is higher. Closed chain motion emphasizes the stability and compression of joints, and limbs are characterized by centrifugal contraction or antagonism against immovable objects (Blackburn & Morrissey, 1998). When a joint is dysfunctional or postural, the central nervous system will adjust the distribution of human power, which will inevitably lead to the compensation of related joints. Functional training integrates multiple joint movements of several muscle groups, which is very functional. According to the joint sequence involved in completing the competitive movement, it designs as much as possible the power chain action with a high degree of coincidence multi-center participation, and multi-joint participation.

2.2 Research on the tennis serve power chain

In the research of the tennis service power chain, some foreign and domestic scholars have made some corresponding achievements. Foreign scholars call it a "kinetic chain", while some domestic scholars call it "whipping action". In the process of tennis serving, lower limbs bend their knees, turn their hips, lift and bend their arms, rotate their forearms inward, and bend their wrists. This force sequence is from the bottom to the top, from the lower limb to the upper limb, providing speed for the service. This sequence is an action chain, and the final stroke is completed according to the sequence.

Bahamonde's research results also show that when serving tennis, the rotation of the body can be seen as a whipping action of the body trunk, arms, and racket (Bahamonde, 2000). The whole tennis serve can be divided into lower limb kicking, turning, hip turning, arm around the shoulder, elbow extension, forearm external rotation, wrist turning, following the ball, and landing feet. Through the above sequence, the tennis serve can be completed, which can maintain the convergence of all parts of the body to the greatest extent and achieve high-quality service

3. Scapula-related research

The manual of body function training movement points out that the scapula, spine, and pelvis, as the main fulcrum of each power chain, play a very important role in the process of energy transmission of upper and lower limbs. On the contrary, if the stability of the scapula, spine, and pelvis decreases, energy leakage will occur in the power chain. Ultimately, it will lead to the reduction of muscle contraction effect and the decline of overall exercise efficiency (Liang, 2014).

Lu Ji believed that the scapula, as the bone connection between the core, spine, and shoulder, as the main fulcrum of the body power chain transmission, played a very important role in the process of upper limb movement energy transmission. If the stability of the scapula decreases, it will lead to the phenomenon of energy leakage in the power chain, which will eventually lead to the reduction of the muscle contraction effect and the decline of the overall exercise efficiency. In the process of volleyball spike, the stability of the scapula makes the transmission of energy on the power chain smoother and maximizes the energy

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reaching the distal link. At the same time, the stability of the scapula provides stable support for the spike of the upper limb, making the muscle contraction at the shoulder joint more sufficient, to improve the volleyball player's spike swing speed (Lu, 2015).

Zhang (2017) Paste two parallel red tapes at an interval of 0.9m in the site; 2. before the test, the athletes put their hands on the inside of the two strips of red tape in a push-up position; 3. after the test, the athlete moves the outer side of the palm from one side of the tape to the other side at the fastest speed, and touches two strips of tape in turn, like a wiper; 4. record the number of times the athlete touches the tape within 15 seconds; 5. repeat 3 times, record the times of each test, with an interval of 60 seconds, and bring the test results into the standardized formula as follows: the formula of scapular stability value is = (68% body weight × (a1+a2+a3) /(3)/ height. Note: 68% of the body weight is the body weight of the subject's trunk, head, and arms.

Conceptual Framework

The conceptual framework for this research is as follows:

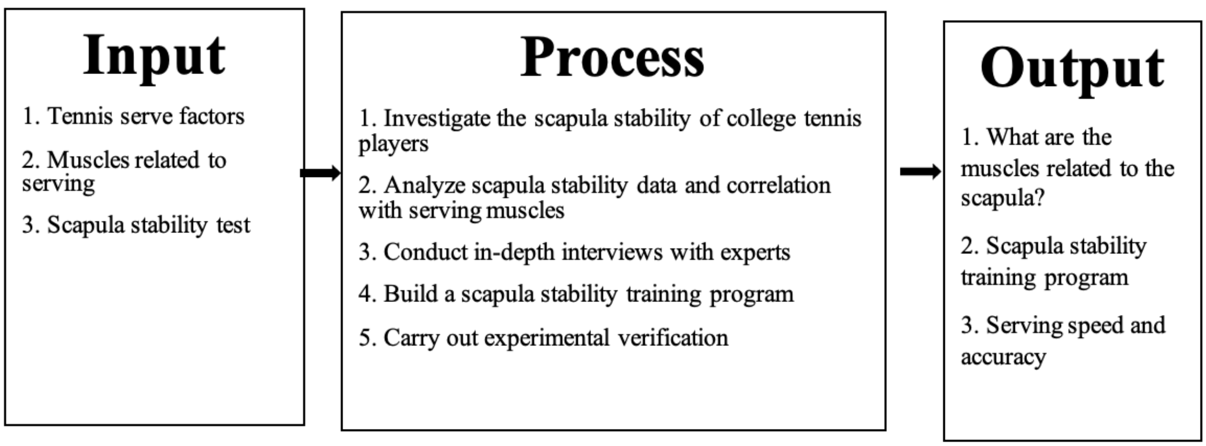

Figure 1 Conceptual Framework

Methodology

Research Tools:

Based on an in-depth literature review, an expert questionnaire was designed. In the early stage of the study, a preliminary survey was carried out. Based on the results of the previous survey, the guidance of relevant experts was sought, the opinions were summarized and sorted out, and a questionnaire was developed. The reliability and validity of the questionnaire were tested. According to the literature and expert opinions, the scapula test method and tennis serve test method are selected.

Population and Sample:

The population of this research was college tennis players in Chinese colleges and universities, 16 college tennis players from Guangzhou Polytechnic of Sports were randomly selected for this study as a sample group. The sample group was divided into an experimental group and a control group, with 8 students in each group (4 males and 4 females). The period of training was 8 weeks, starting from July 2023 to ending in September 2023, before and after the experiment, the scapula stability values, serving accuracy, and serving speed of the experimental group and the control group were tested and collected. After the tennis training class, only the experimental group will perform scapula stability training twice a week (Monday and Wednesday) for 60 minutes each time. This research used literature methods, expert interviews, experiments, and mathematical statistics to conduct experimental research and theoretical analysis on the effects of scapula stability training on the serving speed and accuracy of college tennis players.

Data Collection and Analysis

First, investigate and study the tennis serving action, the muscles related to the serving action, and the stability of the scapula, and select the stability testing method of the scapula that is highly operable, the

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serving accuracy testing method, and the serving speed testing method. Second, conduct in-depth interviews with experts. The muscles involved in scapula stability were identified based on the interview outline. Third, construct a scientific and effective scapula stability training program and conduct IOC testing. Fourth, carry out a scapula stability training intervention experiment in a special tennis class for college students, and test the changes in the speed and accuracy of college students' serves after the intervention experiment.

In this research, calculate the mean (M) and standard deviation (SD) of all variables. The scapula stability, serving accuracy, serving speed, and other data of the experimental group and the control group were compared and analyzed using an independent sample t-test. Paired sample t-test was used before and after the experiment in the experimental group. When P>0.05, it means there is no significant difference between the two groups of data; when P<0.05, it means there is a significant difference between the two groups of data. Excel 2013 was used to record the original data from literature and measurements and to create comparative analysis charts.

Results

The basic information of the experimental group and the control group is as follows:

Table 1 The characteristics of age, height, weight, and BMI of participants by group

Variables	Control Group (n=8)	Experimental Group (n=8)
	Mean+ SD	Mean+ SD
Age (years)	19.50±0.53	20.00±0.53
Height (cm)	171.88±0.09	171.50±0.10
Weight (kg)	64.00±12.34	63.88±8.01
BMI	21.48±2.07	21.72±1.49
Training Experience (year)	2.00±0.00	2.00±0.00

Tests were conducted before the experiment and after the 8-week experiment. The scapula stability, serving accuracy, and serving speed values of the control group and experimental group are shown in Table 2.

Table 2 Average and standard division of scapula stability, serving accuracy and ball speed in each group before and after the experiment

Variables	Control Group (n=8)		Experimental Group (n=8)	
	Pre-test	Post-test	Pre-test	Post-test
	Mean+ SD	Mean+ SD	Mean+ SD	Mean+ SD
scapula stability (score)	6.74±1.05	6.81±1.09	7.08±1.09	9.45±1.33
serving accuracy (score)	28.50±4.34	30.38±5.34	28.86±4.29	35.50±2.67
ball speed (km/h)	109.68±29.53	136.80±23.89	108.38±38.53	122.21±35.71

Before the experiment, the scapula stability, serving accuracy, and ball speed of the experimental group and the control group were tested and the values were significantly compared. The test data are shown in Table 3 Using the independent T-test, there is no statistically significant difference in the scapula stability test scores, serving accuracy, and serving ball speed test scores (P>0.05) between the experimental group and the control group before the experiment. Difference, so that the experimental grouping is established, and the experiment can be carried out.

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Table 3 Pre-test mean comparisons of scapula stability, serving accuracy, and serving speed between the experimental group and the control group were conducted using an independent t-test

Variables	**Group**	**M**	**df**	**t**	**P**
scapula stability	Control Group	6.74	14	0.62	0.54
	Experimental Group	7.08			
serving accuracy	Control Group	28.50	14	0.17	0.87
	Experimental Group	28.88			
serving speed	Control Group	109.68	14	0.08	0.94
	Experimental Group	108.38			

*P<.05

After 8 weeks of scapula stability training, the experimental group and the control group were subjected to post-tests on the scapula stability test, serving accuracy, and serving speed indicators. The test results are shown in Table 4

Using the independent sample T-test, it can be seen from Table 4 that the comparative analysis of the scapula stability test values of the experimental group and the control group after the experiment P=0.001<0.05, there is a statistically significant difference; the experimental group after the experiment Comparative analysis of the test values of the serving accuracy of the players in the experimental group and the control group after the experiment P=0.029<0.05, there is a statistically significant difference; Comparative analysis of the test values of the serving speed of the experimental group and the control group after the experiment P=0.350>0.05, statistically significant There is no significant difference in learning as shown in Figure 2.

Table 4 Post-test mean comparisons of scapula stability, serving accuracy, and serving speed between the experimental group and the control group were conducted using an independent t-test

Variables	**Group**	**M**	**df**	**t**	**P**
scapula stability	Control Group	6.81	14	4.35	0.00*
	Experimental Group	9.45			
serving accuracy	Control Group	30.38	14	2.43	0.03*
	Experimental Group	35.50			
serving speed	Control Group	136.80	14	0.97	0.35
	Experimental Group	122.12			

*P<.05

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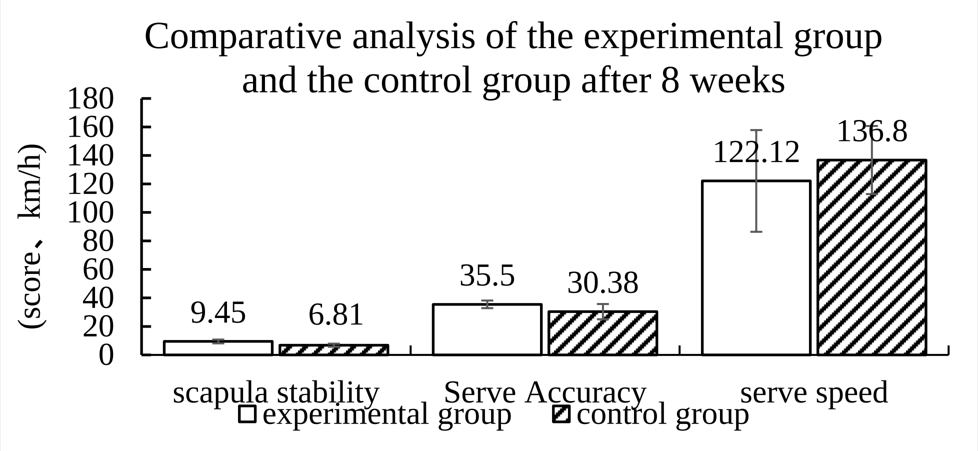

Figure 2 Comparative analysis of scapula stability, serving accuracy, and serving speed between the experimental group and the control group after the experiment

Table 5 Mean comparisons of scapula stability, serving accuracy, and serving speed within the experimental group were conducted using a dependent t-test

Variables	**M**	**df**	**t**	**P**
scapula stability	2.37	7	14.27	0.00*
serving accuracy	6.63	7	9.39	0.00*
serving speed	13.74	7	6.74	0.00*

*P<.05

Through the paired T-test, it can be seen from Table 5 that after 8 weeks of scapula stability training, the mean scapula stability of the students in the experimental group increased from 7.08 to 9.45, an increase of 33.47%. Comparative analysis of scapula stability values P=0.00 <0.05, as shown in Figure 3, there is a statistically significant difference between before and after the experiment.

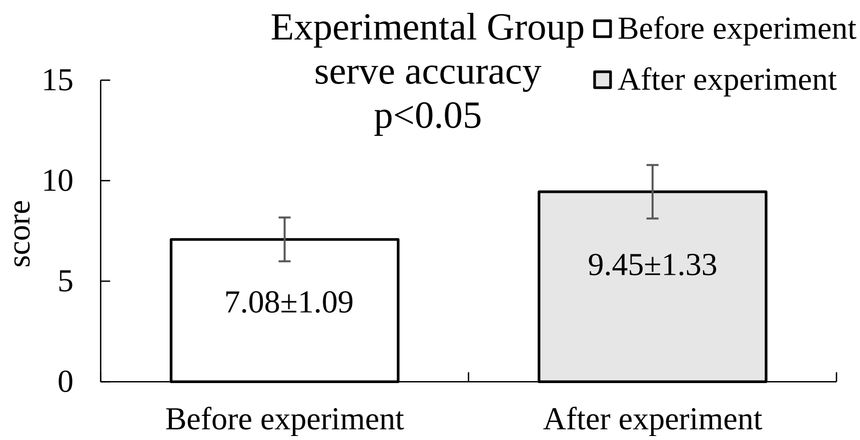

Figure 3 Comparative analysis of scapula stability in the experimental group before and after the experiment

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The average serving accuracy of students in the experimental group increased from 28.88 to 35.50, an increase of 22.92%, comparative analysis of serving accuracy values P=0.00<0.05, as shown in Figure 4, There is a statistically significant difference between before and after the experiment.

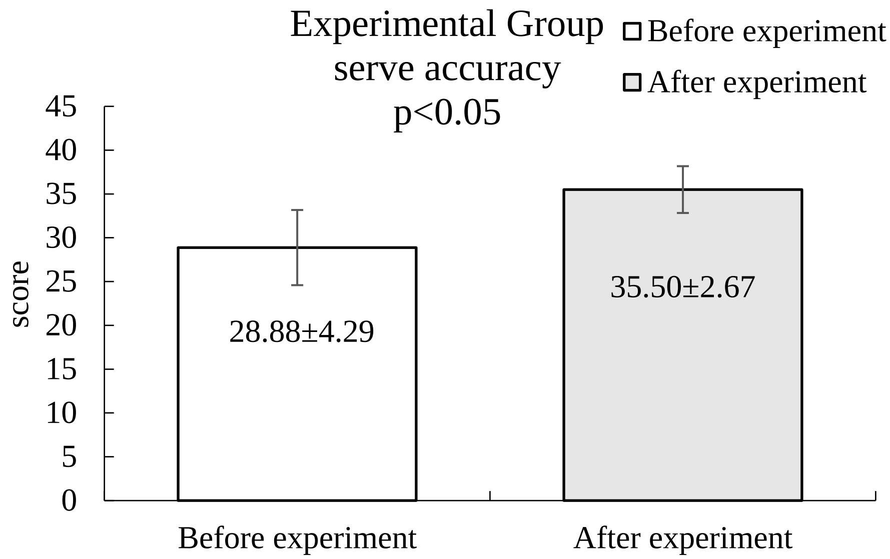

Figure 4 Comparison analysis of serve accuracy of the experimental group before and after the experiment

The average serving speed of the students in the experimental group increased from 108.38 to 122.12, an increase of 12.68%. Comparative analysis of the serving speed value P=0.00<0.05, as shown in Figure 5, before and after the experiment There is a very statistically significant difference.

Figure 5 Comparison analysis of serve speed of the experimental group before and after the experiment

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Conclusion

To investigate the effect of scapular stability training on the serving kinetic chain concerning the speed and accuracy of tennis serves, this study employed a combination of a literature review, a focus group consisting of 17 experts, and experimental training. Volunteer college students, comprising 8 boys and 8 girls, participated as the experimental subjects. They were randomly assigned to either the experimental group or the control group. The experimental group underwent eight weeks of scapular stability training.

The results show that scapular stability and serve accuracy in the experimental group were significantly higher than in the control group ($p < 0.05$). In terms of serving speed, there was no significant difference between the experimental group and the control group ($p>.05$). Within the experimental group, there were significant improvements in scapular stability, serve accuracy, and serve speed before and after the experiment ($p < 0.05$).

Discussion

In this study, the scapula stability training for the experimental group was specifically designed for the scapula stabilizing muscles. Its main feature is the use of low-load intensity training with gradually increasing training time or frequency. Through training, the stabilizing muscles around the scapula can be exercised more easily, so scapula stability training can effectively improve the stability of the shoulder joint. (Zhang Xing, 2017) A 6-week scapula stability training program for college volleyball players to improve scapula stability also confirms this conclusion. (Kolar P, 2014) During the training, through the progressive training methods of adjusting breathing patterns - proprioception training - scapular strength strengthening - and stable function transformation, the organic combination of functional training and special training is emphasized, thus focusing on the development of the neuromuscular system. Holistic development, focusing on the unity of consciousness and muscles, strengthens the coordinated development of deep small muscles, thereby improving the accuracy of serving.

The experimental group's scapula stability value, serving accuracy, and serving speed increased by 33.47%, 22.92%, and 12.68% respectively before and after the experiment, while the serving speed value increased slightly. This shows that scapula stability training still has a positive effect on improving serve speed. This may stem from two aspects. First, all muscles play a role in power and stability to some extent. Although the experimental subjects generally promoted the improvement of stabilizing muscle strength when practicing scapula stability training, they still exercised the dynamic muscles of the shoulder. Second, scapula stability training significantly improved the shoulder joint stability strength of the athletes in the experimental group, and the role of scapula stability is to improve force transmission and support for movements. Therefore, the development of shoulder joint stability strength is an important guarantee for improving the speed of serving. It makes the use of dynamic force more concentrated and effective, and the speed of serving will naturally increase. (Lu Ji, 2015) During the volleyball spiking process, the stability of the scapula makes the energy transfer along the dynamic chain smoother and maximizes the energy reaching the distal link. At the same time, the stability of the scapula provides support for the spiking action of the upper limbs. Stable support enables the muscles at the shoulder joint to contract and exert force more fully, thereby increasing the speed of the volleyball player's spike arm swing, which also confirms this finding.

The control group only participated in the usual tennis class training. Although the scapula stability value and serving accuracy of the players in the experimental group were significantly improved, there was no significant difference in serving speed with the experimental group. Similar studies have shown that strength training is ineffective in increasing serve speed. Strength training programs are commonly believed to be beneficial for athletic performance. Athletes in power events are confident that their performance will improve with increased strength. However, athletes involved in more complex motor skills, such as tennis, may question the value of strength training. A study investigated the effects of a 6-week isotonic strength training program on the accuracy and velocity of the serve in college-aged female tennis players. The training program involved specific upper body exercises using free weights, and flexibility exercises were also incorporated. The training program involved specific upper body exercises using free weights, and flexibility exercises were also incorporated. results showed significant improvements in strength, flexibility, placement, and accuracy in the resistance-trained group.

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Recommendation

1.In tennis serve training, scapula stability training should be strengthened. We should not only focus on tennis technical and tactical training, traditional strength training, etc. However, scapula stability training cannot replace traditional strength training and should be combined with traditional strength training.

2. Due to the limitations of the objective conditions of this experiment, this article only tested and analyzed the stability of the scapula, service accuracy, and service speed. In the future, other indicators of tennis skills and tactics can be included in the research scope, such as service stability, forehand and backhand baseline shots Ball stability, and more. It can also be extended to other sports.

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