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ORIGINAL ARTICLE

Retrospective Study

Correlation analysis of national elite Chinese male table tennis players' shoulder proprioception and muscle strength

Xue-Dong Shang, En-Ming Zhang, Zhen-Lei Chen, Lei Zhang, Jing-Hua Qian

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Abstract

BACKGROUND

Shoulder is the most injured part in table tennis players, and it takes multiple roles in transmitting power and striking the center of the ball during the stroke. Proprioception is strongly correlated with high level of athletic performance. It is customary to assume that there is a correlation between proprioception and muscle strength and therefore proprioceptive assessment and rehabilitation is often neglected.

AIM

To investigate the correlation between isokinetic muscle strength and proprioception in the internal and external rotation muscle groups of elite Chinese male table tennis players, to provide reference for physical training and rehabilitation of elite table tennis players.

METHODS

A total of 19 national elite table tennis players from the Chinese National Table Tennis Team were recruited in this research. All of them had more than 10 years training experience and had participated major competitions such as the National Games and World Youth Championships. IsoMed 2000 was used to test the peak torque of internal and external rotation isokinetic concentric contraction of the athletes' bilateral shoulder joints at low speed (60°/s) and high speed (180°/s)

respectively; IsoMed 2000 was used to conduct the Joint Position Reproduction test to evaluate the athletes' proprioceptive ability capacity at low speed (60°/s) and high speed (180°/s) respectively. If the data satisfied the normal distribution, the correlation between the differences in peak torque s and angles in different directions was analyzed using a Pearson simple linear model; otherwise, Spearman correlation analysis was used. The comparison of proprioceptive ability between the table tennis racket-holding hand and non-racket-holding hands was performed using independent samples *t*-test if the data satisfied a normal distribution; otherwise, the Mann-Whitney *U* test was used.

RESULTS

There was no direct linear correlation between the strength and proprioceptive correlation analysis at slow speed (60°/s) and fast speed (180°/s) in the racket-holding hand; At the slow speed (60°/s) and fast speed (180°/s), there was no correlation between muscle strength and proprioception in the non-racket-holding hand except for the internal rotation variable error (VE) and external rotation relative peak torque, which showed a moderate positive correlation ($r = 0.477$, $P < 0.05$), ($r = 0.554$, $P < 0.05$). The internal rotation's constant error (CE) and VE were 1.06 ± 3.99 and 2.94 ± 2.16, respectively, for the racket-holding hand, and -3.36 ± 2.39 and 1.22 ± 0.93, respectively, for the non-racket-holding hand; the internal rotation's CE, VE of the racket-holding hand was lower than that of the non-racket-holding hand, and there was a highly significant difference ($P < 0.01$).

CONCLUSION

There was no correlation between muscle strength and proprioceptive function in the internal and external rotation of the racket-holding hand's shoulder in elite Chinese male table tennis players. These results may be useful for interventions for shoulder injuries and for the inclusion of proprioceptive training in rehabilitation programs.

Key Words: Elite table tennis player; Shoulder; Proprioception; Muscle strength; Correlation analysis

Core Tip: Increased muscle strength does not necessarily improve spine and shoulder proprioception in table tennis players. Upper limb stabilization and plyometric training, which stimulates the body's proprioceptors and trains the body's muscles, may be recommended exercise therapy.

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INTRODUCTION

Table tennis players need to swing and hit the table tennis readily during training and competition. The shoulder joint takes multiple roles in transmitting power and striking the center of the ball during the stroke[1,2]. Studies have shown that the most injured part of table tennis players is the shoulder[3,4]. Therefore, investigating the correlation between shoulder joint's strength and proprioception will not only help table tennis players improve technical movements and performance, but also will be beneficial for developing scientific and effective training and rehabilitation programs.

The term "Table Tennis Sense" was often mentioned in table tennis. In fact, the term "Table Tennis Sense" is synonymous with proprioception and coordination. Studies have shown that there is strong correlation between coordination and movement agility in ball sports, which means an athlete's ability to perform movements efficiently and quickly depends on the activation of the stabilizing muscles[5]. Meanwhile, there is a correlation between proprioception and high level of athletic performance[6]. With the elevation of shoulder and the increases of soft tissue tension, the proprioception of athlete will also change[7,8], which can affect the control of joint power output in end of range of motion, making shoulder proprioception particularly important. Proprioceptive tests are mainly based on kinesthetic and positional perception[9-11]. There are now many studies on proprioception of the ankle joint, but their methodological choices are flawed, such as not shielding visual interference[12]. Some studies have noted the problem and measured wrist sensory thresholds after excluding auditory and visual distractions[13], but exploration of kinesthetic and positional perception is still lacking in proprio-

ception.

In this study, the Joint Position Reproduction test (JPR)[14-16] was selected to perform active JPR for internal and external rotation movements of the shoulder joint. Not only did it exclude other visual-auditory interference factors, but also meet the sport-specific requirements of table tennis. The aim of this study was to investigate the relationship between isokinetic muscle strength characteristics and proprioception in the internal and external rotation muscle groups of elite Chinese male table tennis players, and to provide a reference for physical training and rehabilitation of elite table tennis players.

MATERIALS AND METHODS

Study design

In this study, a cross-sectional survey in a descriptive study was used: IsoMed 2000 was used to test the peak torque of internal and external rotation concentric contraction of the athletes' bilateral shoulder joints at low speed (60°/s) respectively; the JPR test was used to evaluate the athletes' proprioceptive ability capacity. Since the proprioceptive ability is easily disturbed by many factors, the proprioceptive test was performed firstly, and then the isokinetic strength test was performed after 5 min rest.

Study subjects

Total 19 national elite athlete level table tennis players from the Chinese National Table Tennis Team were recruited into this research. All of them had more than 10 years training experience and had participated major competitions such as National Games of the People's Republic of China and World Youth Championships. The basic information of the athletes is shown in Table 1.

Proprioceptive test of shoulder joint

The IsoMed 2000 (D. & R. Ferstl GmbH, Germany) was used to perform proprioceptive tests and isokinetic muscle strength on the athletes, and it has high reliability and validity according to numerous studies[15,17]. As an important tool for studying the physiological basis of athletic ability and technical movement level, it can provide practical help in improving the technical movement of athletes and improving the scientific level of training. Along with the measurement of isokinetic muscle strength, many researchers have also used IsoMed 2000 to measure proprioception[18,19] to assess an individual's ability to actively repeat a reference position.

The starting position for internal and external shoulder rotation was 90 degrees of abduction, 90 degrees of elbow flexion and 30 degrees of humeral external rotation. The preset values were 40 degrees of external rotation and 20 degrees of external rotation (*i.e.*, 10 degrees each of internal and external rotation under the starting position). The JPR for rotation was then performed sequentially, with a total of seven measurements (the first three for movement learning and the last four for the formal test). The subject actively moved the arm (shoulder joint) from the initial position to a predetermined target angle for 3 s, reminded the subject of this predetermined target position, and then returned to the neutral position. The subject then moved actively and pressed the pause button when the target angle was felt and the actual angle at this point was recorded. The shoulder proprioceptive ability was evaluated by comparing the difference between the actual position and the target position, and the evaluation indexes included constant error (CE), variable error (VE), and absolute error (AE). These indicators not only compare the magnitude and direction of error, but also evaluate the stability of error[20,21] (Table 2).

Isokinetic muscle strength testing of shoulder joints

The IsoMed 2000 (D. & R. Ferstl GmbH, Germany) was used to perform isokinetic muscle strength test. To meet the sport-specific needs of table tennis players and to reflect the characteristics of the upper limb muscle strength at different speeds and to consider safety issues, the protocol was set to bilateral shoulders and slow speed was utilized firstly and then fast speed. The isokinetic muscle strength testing system was selected to quantify the strength of the internal and external shoulder rotation muscles for 5 repetitions at slow speed (60°/s) and 25 repetition at fast speed (180°/s), testing the dominant side and then testing the non-dominant side in the same way. The peak torque for external and internal rotation of the shoulder joint were selected bilaterally, resulting in a low velocity external rotation peak torque, a low velocity internal rotation peak torque, a high velocity external rotation peak torque and a high velocity internal rotation peak torque (Figure 1).

Statistical analysis

SPSS 20.0 (Statistical Package for Social Science, Chicago, IL, USA) software was used for statistical analysis and calculations. The Kolmogorov-Smirnov test was used to test the normality of the data. If the data satisfied the normal distribution, the correlation between the differences in peak torque and joint position at different directions was analyzed using a Pearson simple linear model. Otherwise, Spearman correlation analysis was used. The comparison of proprioception between the table tennis racket-holding hand and non-racket-holding hands was performed using independent samples *t*-test if

Table 1 Basic Information of the table tennis players (mean ± SD)

Subjects	Age (yr)	Height (cm)	Body weight (kg)	Training experience (yr)	Level of athlete
n = 19	17.87 ± 1.49	176.31 ± 4.19	66.67 ± 3.92	> 10	National Elite athlete

Table 2 Calculation and significance of proprioceptive evaluation indicators of the shoulder joint

Test	Evaluation index and its calculation methods	Meaning of the indicator
Joint position reproduction test of the shoulder joint	AE = (|Original error 1| + |Original error 2| + … + |Original error n|)/n	No positive or negative direction is considered. Only calculate the absolute error between the end position and the start position.
	CE = [(Original error 1) + (Original error 2) + … + (Original error n)]/n	Taking the positives and negatives in direction into account to evaluate overall the error in the given direction of movement, reflecting whether the movement pattern overall exceeds or fails to reach the target.
	VE =$\sqrt{}${[(Original error 1-CE)^2 + (Original error 2-CE)^2 + … + (Original error n-CE)^2]/n}	Reflects the variability and consistency between the results of several position reproduction, regardless of the accuracy of the JPR.

AE: Absolute error; CE: Constant error; VE: Variable error; JPR: Joint Position Reproduction test.

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Figure 1 Isokinetic muscle strength testing of shoulder joints with IsoMed 200.

the data satisfied a normal distribution. Otherwise, the Mann-Whitney U test was used. Significant differences were considered at $P < 0.05$ and highly significant difference were considered at $P < 0.01$. All indicators are expressed in mean ± SD. In this study, Cohen's d was used to evaluate the effect size. The specific evaluation standard was: 0.1 represent a small effect size; 0.3 represent a medium effect size; and 0.5 represent a large effect size.

RESULTS

Correlation analysis of the data from the proprioceptive test and isokinetic muscle strength test of the racket-holding hand

Slow speed: The strength and proprioceptive correlation analysis at slow speed (60°/s) is shown in Table 3. The results indicate that there is no direct linear correlation between the two data groups.

Fast speed: The strength and proprioceptive correlation analysis at fast speed (180°/s) is shown in Table 4. The results of the study indicate that there is no direct linear correlation between the two data groups.

Correlation analysis of the data from the proprioceptive test and isokinetic muscle strength test of the non-racket-holding hand

Slow speed: At the slow speed (60°/s), there was no correlation between muscle strength and proprioception, *etc.*, except for the internal rotation VE and external rotation relative peak torque, which showed a moderate positive correlation ($r = 0.477$, $P < 0.05$), as shown in Table 5.

Fast speed: At fast speed (180°/s), there was no correlation between forces and proprioception, *etc.*, except for the internal rotation VE and the external rotation relative peak torque, which showed a moderate positive correlation ($r = 0.554$, $P < 0.05$), as shown in Table 6.

Comparison of proprioceptive ability between the racket-holding hand and the non-racket-holding hand

From the data exploration, the internal rotation's CE and VE were 1.06 ± 3.99 and 2.94 ± 2.16, respectively, for the racket-holding hand, and -3.36 ± 2.39 and 1.22 ± 0.93, respectively, for the non-racket-holding hand. as seen in Table 7, the internal rotation CE, VE of the racket-holding hand was lower than that of the non-racket-holding hand, and there was a highly significant difference ($P < 0.01$).

DISCUSSION

In the present study, the index chosen for muscle strength is the peak torque, which represents the maximum torque of a muscle in the given direction of movement and has a high reliability. It is widely used in isokinetic muscle strength testing[22]. The observed metric for proprioception is the magnitude of the absolute error angle value, which quantifies abstract proprioception into data and also adequately represents the ability of position and kinesthetic perception, which is also considered as the gold standard in previous studies in the field of proprioception[14].

The relationship between proprioception and muscle strength in the racket-holding hand

From the study, no correlation was found between proprioception and muscle strength in the internal and external rotation of the shoulder joint of the racket-holding hand. However, because many of the receptors of proprioception, such as the muscle spindle and tendon organ, are in muscle tissue, it is customary to assume that there is a correlation between proprioception and muscle strength, especially after the onset of injury, when both muscle strength and proprioception are reduced[23,24]. However, in the present study, there was no significant difference($P > 0.05$) between isokinetic muscle strength and proprioception in the shoulder joint of the racket-holding hand after the correlation coefficient was used to evaluate both in the fast and slow speed conditions, which is consistent with the findings of Wang[25-27].

The present study concluded that in shoulder motion, the muscle spindle is one of the main providers of joint position sensation in the middle range of joint motion, while the receptors located above the ligaments and joint capsule are not fully activated. They can only generate tension after being subjected to deformation to receive stimuli[28]. At the same time, many proprioceptors are stimulated at the end of the range of motion rather than at the midpoint of the range of motion[8,29]. In the case of the shoulder joint, the end of the external rotation is stimulated more often[8]. Therefore, it is possible that proprioceptive abilities were not fully activated during the experiment.

Secondly, the power and proprioceptive conduction pathways are not identical. The processing centers for proprioception are in the posterior part of the posterior central gyrus and paracentral lobule, whereas the motor conduction pathway begins in the anterior part of the precentral gyrus and paracentral lobule[30]. Although the muscular and tendon organ are attached to the muscle, they are essentially two different conduction pathways. The excellent proprioceptive ability of athletes is due to the gradual desensitization of the Golgi tendon organ with prolonged training, increased sensitivity of the musculocutaneous spindle and increased adaptation of peripheral nerves to improve joint position sense[31]. Proprioception does not change with force, and it is thought that proprioception only changes with changes in the muscle spindle and intra-articular proprioceptors[16,32]. Sometimes sports injuries

Table 3 Correlation analysis of strength and proprioception at 60°/s in the shoulder joint of the racket-holding hand in table tennis players

		Absolute peak torque of external rotation	Relative peak torque of external rotation	Absolute peak torque of internal rotation	Relative peak torque of internal rotation
External rotation AE	Spearman	-0.055	-0.148	-0.059	-0.178
	P value	0.818	0.533	0.806	0.454
External rotation CE	Spearman	-0.234	-0.315	-0.197	-0.344
	P value	0.321	0.176	0.405	0.137
External rotation VE	Pearson	0.302	0.136	0.330	0.162
	P value	0.196	0.568	0.155	0.495
Internal rotation AE	Pearson	0.223	0.018	0.199	0.001
	P value	0.344	0.939	0.399	0.997
Internal rotation CE	Pearson	0.175	-0.139	0.220	-0.097
	P value	0.459	0.558	0.351	0.683
Internal rotation VE	Spearman	-0.024	0.086	-0.097	0.043
	P value	0.920	0.719	0.685	0.857

AE: Absolute error; CE: Constant error; VE: Variable error.

Table 4 Correlation analysis of strength and proprioception at 180°/s in the shoulder joint of the racket-holding hand in table tennis players

		Absolute Peak torque of external rotation	Relative peak torque of external rotation	Absolute peak torque of internal rotation	Relative peak torque of internal rotation
External rotation AE	Spearman	-0.111	-0.150	-0.204	-0.214
	P value	0.640	0.529	0.388	0.366
External rotation CE	Spearman	-0.113	-0.347	-0.123	-0.420
	P value	0.636	0.133	0.604	0.065
External rotation VE	Pearson	0.033	0.057	0.040	0.091
	P value	0.890	0.812	0.868	0.704
Internal rotation AE	Pearson	0.114	0.082	0.066	0.076
	P value	0.633	0.732	0.782	0.749
Internal rotation CE	Pearson	0.168	-0.145	0.245	-0.105
	P value	0.478	0.542	0.297	0.660
Internal rotation VE	Spearman	0.053	0.221	-0.081	0.117
	P value	0.826	0.349	0.736	0.623

AE: Absolute error; CE: Constant error; VE: Variable error.

cause damage not only to the muscle fibers but also to the proprioceptors attached to the muscle, which may explain the simultaneous decrease in proprioception and strength after injury.

Finally, the study population was National Elite Athletes, which may not have the same traits as the healthy population. One study[7] assessed the relationship between strength and proprioception and concluded that strength was associated with power perception in proprioception, while there was no significant relationship with joint position perception. In the methodology of proprioception, it was also stated[33] that tests for different aspects of proprioception are not inherently correlated and that it is one-sided to represent proprioception through one test method. Therefore, this study can only show that there is no significant correlation between positional perception and muscle strength.

Table 5 Correlation analysis of strength and proprioception at 60°/s in the shoulder of non-racket-holding hands of table tennis players

		Absolute peak torque of external rotation	Relative peak torque of external rotation	Absolute peak torque of internal rotation	Relative peak torque of internal rotation
External rotation AE	Pearson	-0.044	0.063	-0.077	0.041
	P value	0.855	0.793	0.747	0.863
External rotation CE	Spearman	-0.071	0.068	-0.027	0.072
	P value	0.765	0.774	0.909	0.762
External rotation VE	Spearman	-0.203	-0.156	-0.138	-0.103
	P value	0.391	0.510	0.561	0.666
Internal rotation AE	Pearson	-0.042	0.093	-0.095	0.050
	P value	0.860	0.695	0.690	0.835
Internal rotation CE	Pearson	0.084	-0.015	0.118	0.020
	P value	0.725	0.950	0.620	0.932
Internal rotation VE	Spearman	0.375	0.477[a]	0.289	0.384
	P value	0.103	0.033[a]	0.217	0.094

[a]$P < 0.05$, muscle strength *vs* proprioception.
AE: Absolute error; CE: Constant error; VE: Variable error.

Table 6 Correlation analysis of the strength and proprioception at 180°/s in the shoulder joint in the non-racket-holding hand of table tennis players

		Absolute peak torque of external rotation	Relative peak torque of external rotation	Absolute peak torque of internal rotation	Relative peak torque of internal rotation
External rotation AE	Pearson	-0.266	0.046	-0.351	-0.025
	P value	0.257	0.847	0.129	0.917
External rotation CE	Spearman	-0.236	-0.099	-0.065	-0.093
	P value	0.318	0.679	0.786	0.697
External rotation VE	Spearman	0.040	0.083	-0.026	0.136
	P value	0.867	0.729	0.914	0.569
Internal rotation AE	Pearson	0.003	-0.070	-0.087	-0.120
	P value	0.990	0.771	0.715	0.615
Internal rotation CE	Pearson	-0.142	0.163	-0.076	0.184
	P value	0.551	0.492	0.751	0.437
Internal rotation VE	Spearman	0.202	0.554[a]	-0.226	0.389
	P value	0.394	0.011[a]	0.339	0.090

[a]$P < 0.05$ forces *vs* proprioception.
AE: Absolute error; CE: Constant error; VE: Variable error.

A study[34] performed bench press strength training on a population with exercise habits and found that after 8 wk of intervention, subjects had increased shoulder joint strength and improved accuracy of position reproduction and attributed the increase in proprioception to their increased strength because of the increased sensitivity of the muscle spindle through strength training, which allows the input of many signals related to proprioception. However, Salles *et al*[34] interpretated the possibilities only on the basis of experimental results and theoretical situations, and in the above experiments only tested proprioception in the direction of rotation, which is not comprehensive enough to prove a relationship between the two. Similarly, Boarati *et al*[35] performed similar training and the results did not improve proprioceptive abilities.

Table 7 Comparison of the Internal and external rotation's absolute error, constant error and variable error of the racket-holding and the non-racket-holding hand

	External rotation AE	External rotation CE	External rotation VE	Internal rotation AE	Internal rotation CE	Internal rotation VE
Z value	-0.947	-1.244	-0.987	-0.906	-3.991	-3.138
P value	0.355	0.221	0.327	0.369	< 0.01[a]	< 0.01[a]

[a]*P* < 0.01, the internal rotation constant error, variable error of the racket-holding hand *vs* that of the non-racket-holding hand.
AE: Absolute error; CE: Constant error; VE: Variable error.

The relationship between proprioception and power in the non-racket-holding hand

This study found a positive correlation between the VE of internal rotation and relative peak torque of external rotation in the non-racket-holding hand in both fast and slow speed conditions (see Table 5 and Table 6).

Firstly, the inconsistency between the results of the non-racket-holding hand and those of the racket-holding hand may be explained by the fact that the racket-holding hand, as the dominant measure of the player, has undergone more than a decade of specialized training in table tennis and has undergone adaptive changes in both shoulder joint posture and structural morphology, and as table tennis is a typically asymmetrical sport, the non-racket-holding hand is weaker than the racket-holding hand both in terms of strength and proprioception, and therefore more closely resembles the normal population.

Secondly, the internal rotational VE represents the stability, not the accuracy, of the internal rotational proprioception of the shoulder joint in the non-racket-holding hand. In contrast, when the shoulder joint performs an internal rotation movement, the external rotation muscles coincide with a centrifugal contraction, which better helps the shoulder joint to perform a controlled and stable coordinated movement. Therefore, the two are correlated.

Furthermore, injure occurs when there is an imbalance in shoulder joint muscle strength. Studies have shown[19] that swingers and throwers have much stronger internal rotation muscles than athletes in other sports, and that these sports will lead to more imbalances in rotator cuff musculature, and Ellen *et al*[36] found that internal shoulder rotation muscles develop selectively relative to external shoulder rotation muscles (a specific characteristic) and occur at a very young age when they were analyzed for isokinetic muscle strength characteristics. Therefore, the imbalance in shoulder muscle strength can lead to problems in shoulder function and a tendency to cause injury to the rotator cuff muscle groups[37].

The above demonstrates the importance of the external rotation muscles of the shoulder joint-combined with the fact that in table tennis, the shoulder joint performs an inward, forward flexion and inward rotation movement when the player is striking the ball with a forehand loop. As the table tennis player has well-developed chest muscles, it is even more important for the infraspinatus and teres minor muscles to perform centrifugal movements to accurately hit the center of the ball and complete the technical movement.

Comparison of proprioception between the racket-holding hand and non-racket-holding hand

In this study, it was shown that the CE and VE of the racket-holding hand during inward rotation are smaller than those of the non-racket-holding hand, indicating that the directionality, accuracy, and stability of the racket-holding hand are better than those of the non-racket-holding hand during the inward rotation of the shoulder joint. This is clearly the result of years of specific training.

Lage number of repetitive open-chain movements have a significant improvement on the proprioceptive capacity of the shoulder joint[38]. In contrast, the compression to which the joint capsule is subjected during closed-chain training provides proprioceptive stimulation, promoting synergistic activity of the upper shoulder muscles and improving joint stability[39]. There is also super-isokinetic training, which stimulates proprioception at the end of the joint to a greater extent[40], and numerous studies have shown that Plyometric training improves proprioceptive abilities[32,41]. These movement patterns are often found in table tennis technical training and specific physical training.

In summary, these results will assist in the development of a rehabilitation program, which should include both plyometric and proprioceptive training. The above results showed that improvements in muscle strength do not necessarily improve proprioception in the spinal and shoulder joints. Finding a method of training that can train both muscle strength and endurance as well as proprioception can significantly improve performance and save time and medical costs. Upper limb stabilization and plyometric training, which stimulates the body's proprioceptors and trains the body's muscles, may be a recommended exercise therapy. In table tennis, in addition to explosive, multi-ball training program can be enhanced by performing many repetitive movements to improve the stability of the landing point and improve proprioceptive abilities.

CONCLUSION

There is no correlation between muscle strength and proprioceptive function in the internal and external rotation of the shoulder in elite Chinese male table tennis players. These results may be useful for interventions for shoulder injuries and for the inclusion of proprioceptive training in rehabilitation programs.

ARTICLE HIGHLIGHTS

Research background

With the constant change of the rules of table tennis, more and more table tennis players emerge, which puts forward higher requirements for the awareness of landing point and the coordination of hitting. The sense of motion and position in proprioception is of great significance to the control of limbs and the judgment of landing points, so the proprioception of table tennis players is evaluated and tested.

Research motivation

Shoulders are the most injured part in table tennis players because the joint has multiple roles in transmitting power and striking the center of the ball during the stroke. Proprioception is strongly correlated with high level of athletic performance. It is customary to assume that there is a correlation between proprioception and muscle strength, and therefore, proprioceptive assessment and rehabilitation are often neglected.

Research objectives

This study was performed to investigate the correlation between isokinetic muscle strength and proprioception in the internal and external rotation muscle groups of elite Chinese male table tennis players, to provide reference for physical training and rehabilitation.

Research methods

The subjects were elite players from the Chinese National Table Tennis Team. All of them had > 10 years' training experience and had participated in major competitions such as the National Games and World Youth Championships. IsoMed 2000 was used to test the peak torque of internal and external rotation isokinetic concentric contraction of the athletes' bilateral shoulder joints at low speed (60°/s) and high speed (180°/s). IsoMed 2000 was used to conduct the Joint Position Reproduction test to evaluate the athletes' proprioceptive capacity at low speed (60°/s) and high speed (180°/s).

Research results

At slow speed and fast speed, there is no direct linear relationship between hand strength and proprioceptive correlation analysis. At slow speed and fast speed, there is a moderate positive correlation except for internal spin variable error (VE) and external spin relative peak torque. The internal rotation constant errors (CE) and VE were 1.06 ± 3.99 and 2.94 ± 2.16 for handgrip, and -3.36 ± 2.39 and 1.22 ± 0.93 for non-handgrip. The internal rotation CE and VE of handgrip were significantly lower than those of non-handgrip ($P < 0.01$).

Research conclusions

There was no correlation between muscle strength and proprioceptive function in the internal and external rotation of the shoulder of the racket-holding hand in elite Chinese male table tennis players. These results may be useful for interventions for shoulder injuries and for the inclusion of proprioceptive training in rehabilitation programs.

Research perspectives

Proprioception is a complex concept, and this study only explored the sense of position and movement, but did not study the sense of speed and force. It also links proprioception to specific tests, such as hitting points, which can help improve performance.

FOOTNOTES

Author contributions: Shang XD and Zhang EM contributed equally to this work; both Shang XD and Qian JH are the corresponding authors; Shang XD, Zhang EM, Chen ZL, Zhang L and Qian JH designed the research study; Shang XD, Zhang EM, and Qian JH performed the research; Shang XD, Zhang EM, Chen ZL and Zhang L analyzed the data and wrote the manuscript; and all authors have read and approve the final manuscript.

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