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ARTICLE

Biomechanical Analysis of Tai Chi (Eight Methods and Five Steps) for Athletes' Body Balance Control

Yuanyuan Feng*

College of Physical Education, Sichuan Agricultural University, Ya'an, 625014, China

*Corresponding Author: Yuanyuan Feng. Email: juaneyuan0873@yeah.net

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ABSTRACT

Background: The increasing number of Tai Chi practitioners has led to extensive attention from researchers regarding the role of Tai Chi exercise. Numerous studies have been conducted through various experiments to examine the effects of Tai Chi on physical and mental improvement. **Objective:** This paper aims to investigate the effect of practicing Tai Chi (eight methods and five steps) on athletes' body balance control ability from a biomechanical perspective. **Methods:** Twenty male athletes were randomly divided into two groups. They had no significant differences in age, height, weight, and training time. The Tai Chi group performed Tai Chi (eight methods and five steps) exercises for nine weeks. Practice sessions were scheduled for every Monday, Wednesday, and Friday, each lasting 50 min. The blank group did not perform any exercises. After nine weeks, the athletes in both groups underwent testing for the one-legged stance with eyes closed, Y-balance test (YBT) score, and plantar pressure. **Results:** After the experiment, the one-legged stance with eyes closed of the Tai Chi group was 151.36 ± 48.77 s. The scores of the left and right sides of the YBT were 101.84 ± 5.97 and 100.59 ± 5.66, which were significantly higher than 80.33 ± 31.52 s, 96.12 ± 7.33, and 97.64 ± 8.12 in the pre-experimental period. In the results of the plantar pressure test, when the athletes stood with both feet and eyes closed, the EA was 23.46 ± 6.86 mm^2, Delta X was 7.64 ± 1.03 mm, and Delta Y was 5.88 ± 0.75 mm, which were significantly different from those in the blank group (55.64 ± 7.98 mm^2, 12.21 ± 1.27 mm, and 8.97 ± 50.86 mm) ($p < 0.05$); when they stood with both feet and eyes open, the EA was 27.64 ± 6.73 mm^2, and Delta X was 7.31 ± 0.56 mm, which were significantly different from those in the blank group (40.66 ± 5.84 mm^2 and 9.87 ± 0.84 mm. **Conclusion:** Practicing Tai Chi (eight methods and five steps) can extend the duration of standing with eyes closed, improve YBT scores, and reduce EA, Delta X, and Delta Y values, thus enhancing athletes' body balance control.

KEYWORDS

Tai Chi; eight methods and five steps; athlete; body balance; biomechanics; Y-balance test score; plantar pressure test

1 Introduction

Tai Chi, also known as Taichiquan, is a traditional martial art originating in China [1] and dating back to the Ming and Qing dynasties. It can be considered as a low-intensity aerobic exercise. It consists of eight methods and five steps as the basic movements. As a martial art that combines rigidity and flexibility, internal and external training, Tai Chi is slow, gentle, and effective in both attack and defense. It

encompasses profound philosophy under the influence of traditional philosophy. At the same time, Tai Chi incorporates theories from traditional medicine to improve cognitive brain function [2]. Therefore, it is useful for strengthening the body and adjusting the mind [3], and can alleviate anxiety, depression, sleep disorders, and other conditions [4]. With the development of society, Tai Chi has now evolved into a popular form of exercise with over 300 million practitioners worldwide. Body balance control refers to the ability to adjust the center of gravity and maintain bodily equilibrium promptly when in an unstable position. Good body balance control is not only beneficial for athletes to improve their sports performance, but it is also important for the human body to perform daily activities. How to improve the body balance control ability has received extensive attention from researchers [5]. Altinkok et al. [6] studied the balance ability of children aged 5–9 years old who underwent gymnastics training and tested their dynamic and static balance abilities. They found through experiments that the balance ability of children aged 5–9 years old varied according to their age. Andreu-Caravaca et al. [7] studied the effect of aerobic training (AT) on balance in patients with multiple sclerosis (MS) and found that balance was significantly improved in the AT group through a study involving 1,070 MS patients. Nilgün [8] studied the relationship between limb muscle thickness and functional capacity, balance, and falls in 50 elderly people aged over 65 years old. It was found that thigh muscle thickness was negatively correlated with walking speed and the timed up-and-go test, and positively correlated with the chair stand test, indicating a relationship between muscle thickness in the lower limbs and human balance ability. Kang et al. [9] analyzed the effects of stretching and strengthening exercises on pain and balance in patients with chronic low back pain (CLBP) and selected forty-two patients with CLBP as research subjects. After an eight-week experiment, they found significant within-group changes on the Berg balance scale ($p < 0.05$) after stretching and strengthening exercises. Tai Chi is a traditional Chinese martial art, and numerous studies have demonstrated its unique role in promoting physical fitness [10]. It has shown improvements in various chronic diseases [11] such as breast cancer [12], depression [13], Parkinson's disease [14], high blood sugar levels [15], and hypertension [16]. Song et al. [17] investigated the impact of traditional Chinese martial arts on the quality of life (QOL) in patients with primary hypertension and analyzed the effects of qigong, Tai Chi, and five-animal exercises. They found that both Tai Chi and qigong had significant influences on QOL, suggesting that Tai Chi may be an effective therapy for improving the QOL in patients with primary hypertension. Li et al. [18] conducted a literature survey analysis to investigate the impact of traditional Chinese exercise on cognitive function improvement. Their research revealed that between 2001 and 2020, a total of 406 relevant articles were published in the Web of Science Core Collection (WoSCC), and the number of publications each year was increasing. These findings indicated that traditional Chinese exercise was receiving growing attention as a method for improving cognition. In their study conducted by Yu et al. [19], they utilized neuroimaging techniques to explore the potential impact of Tai Chi on brain morphology regulation, functional homogeneity and connectivity, regional activities as well as macroscopic network activities. They found possible connections between these cerebral changes and the beneficial effects of Tai Chi, including improving motor function, pain perception, metabolic profile, cognitive function, mental health, and sleep quality. Cai et al. [20] investigated the effects of Tai Chi on type 2 diabetes mellitus (T2DM) and found that, compared to regular care, Tai Chi could improve glycated hemoglobin levels, fasting blood glucose levels, insulin, body mass index, diastolic blood pressure, and QOL in T2DM patients. Gao et al. [21] investigated the effectiveness of Tai Chi training in improving balance ability among patients with Parkinson's disease. They found that Tai Chi training had beneficial effects on posture control in individuals, effectively reducing limb stiffness, improving limb flexibility in patients with mild to moderate Parkinson's disease, and enhancing their gait and balance functions. Kang et al. [22] conducted a study on 30 female patients with knee osteoarthritis and found that participation in Tai Chi exercise significantly improved the patients' physical fitness and health status indicators. The role of Tai Chi in clinical medicine has been proved in many ways, but in terms of body

balance control ability, it is mostly used in elderly people or patients. There is a lack of research on its effects on athletes' body balance control ability. Tai Chi plays a significant role in improving body balance and control, which is of great practical value for sports that require high levels of balance control, such as gymnastics and skiing. Furthermore, Tai Chi can help athletes enhance their body posture, adjust muscle exertion, and reduce the risk of sports injuries, making it highly meaningful. Furthermore, the practice of Tai Chi not only cultivates self-discipline but also nurtures both body and mind, significantly improving athletes' mental well-being and reducing competitive pressure. Therefore, studying the role of Tai Chi in sports holds great practical significance as it offers athletes more training options and further advances the development of sports science. The ability to control enables athletes to perform complex movements and skills, thereby achieving better athletic performance in competitive sports. It also helps athletes have a better grasp of their bodies, reducing the risk of injuries. Therefore, research on how to improve athletes' body balance control has significant implications for enhancing athletic levels and preventing sports injuries. In order to understand the effects of Tai Chi on improving the body balance control ability of athletes, this paper analyzed the effect of Tai Chi exercises (eight methods and five steps) on the body balance control ability of athletes from a biomechanical perspective and proved the role of Tai Chi exercises (eight methods and five steps), providing a new method for how to improve the body balance control ability of athletes in training. Moreover, this study is beneficial to help athletes further enhance their ability to control body balance to achieve better performance.

2 Research Subjects and Methods

2.1 Research Subjects

Twenty male athletes from the School of Physical Education at Sichuan Agricultural University were used as study subjects according to experience. They were in good mental condition, had no major sports injuries within the past two years, no history of major surgery, and no cardiovascular, cerebrovascular, respiratory and other diseases. They all understood the purpose and procedure of the experiment and signed informed consent. They were randomly divided into two groups. One group was the Tai Chi group, which performed Tai Chi exercises (eight methods and five steps), and the other group was the blank group, which only completed the regular teaching program. The basic information of the two groups is shown in Table 1, and there was no significant difference.

Table 1: Basic information of the study subjects

	Tai Chi group (n = 10)	Blank group (n = 10)
Age/year	20.36 ± 2.21	21.07 ± 1.98
Height/m	1.78 ± 5.64	1.75 ± 6.97
Body weight/kg	65.64 ± 8.12	66.59 ± 9.37
Training time/year	8.12 ± 2.22	8.73 ± 1.86

2.2 Research Methodology

The experiment was conducted for nine weeks, on Monday, Wednesday, and Friday. Each exercise consisted of three parts: warm-up, practice, and relaxation. The first week served as a pre-experiment to help the athletes in the Tai Chi group understand the content of Tai Chi (eight methods and five steps) and learn the key points of the routine. This ensured that after the pre-experiment, the athletes could master all the movements and complete the full set of exercises alone. Weeks 2–8 constituted the period

of the formal experiment. During this period, the Tai Chi group practiced the eight methods and five steps, while the blank group completed the regular teaching program. The practice arrangement of the Tai Chi group is shown in Fig. 1.

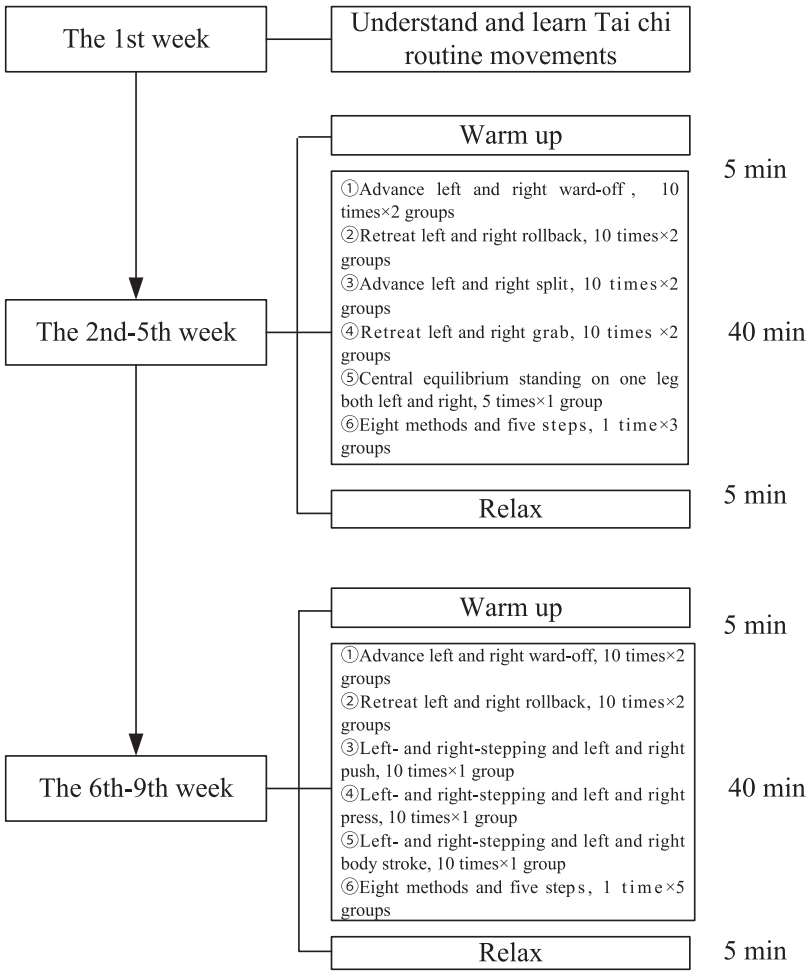

Figure 1: Practice arrangement of the athletes in the Tai Chi group

Of the eight methods and five steps of Tai Chi, the eight methods are the eight forcing methods (Fig. 2), and the five steps are the footwork.

Peng (warding off): the palm of the hand is pushed forward and pushed out from the bottom up.

Lv (rolling back): the athlete uses the body's strength to flex on the opponent's arm to make it fall short.

Ji (pushing): the whole body restrains the opponent's hand with the external force.

An (pressing): apply heavy pressure on the opponent's body quickly, mainly with the palm of the hand or fingers.

Cai (grabbing): use the power of both hands to quickly reverse the enemy's pace.

Lie (splitting): rotate the arm and wrap it around the back side of the opponent to pull it inward or outward laterally and forward.

Zhou (elbowing): strike with the elbow and use inertia to deliver a lethal strike.

Kao (body stroke): the athlete jumps forward and hits the enemy with his body.

Jin (advancing): move one step forward.

Tui (retreating): move one step backward.

Gu (shifting left): turn the head to the left and look.

Pan (shifting right): turn the head to the right and look.

Ding (central equilibrium): stand stably.

The basic set of Tai Chi can be obtained through different combinations of the above movements.

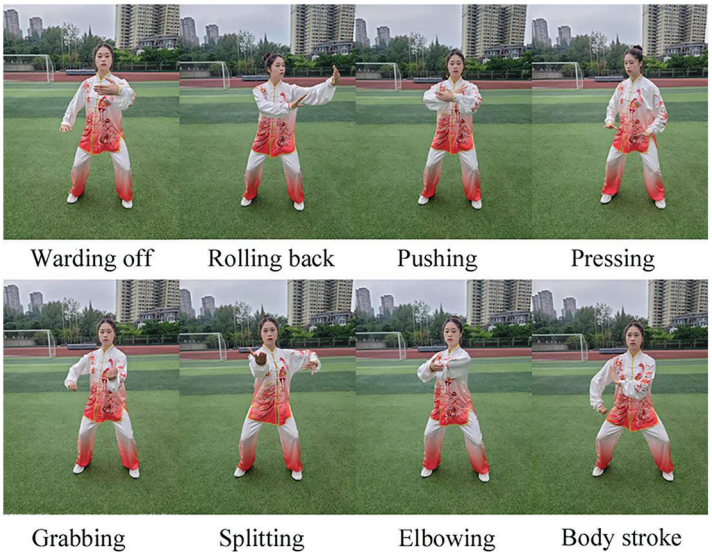

Figure 2: The eight methods in Tai Chi

2.3 Body Balance Control Ability Test Indicators

Before and after the experiment, the static balance ability of both groups of athletes was tested by standing on one leg with their eyes closed [23]. During the test, the athlete placed his hands on his hips, closed his eyes, lifted one leg, and maintained body balance. The total standing time was recorded. The test was stopped when the athlete moved his leg, put it down or opened his eyes. The test was repeated three times, and the best result was taken.

Before and after the experiment, the Y-balance test (YBT) kit [24] (Fig. 3) was used to assess the dynamic balance function of the lower extremities of the athletes in both groups. During the test, the athlete placed his hands on his hips, stood with the tested leg in a standard position on the medial test board, and stretched his non-test leg as far as possible to the anterior, posterior-medial, and posterior-lateral sides of the test leg. He pushed the skateboard to its farthest point before retracting it. The test was repeated three times, with an one minute interval. The YBT score was recorded as a combined value:

Combined value = (anterior value + posterior-medial value + posterior-lateral value)/(3 × lower limb length of the tested leg) × 100%

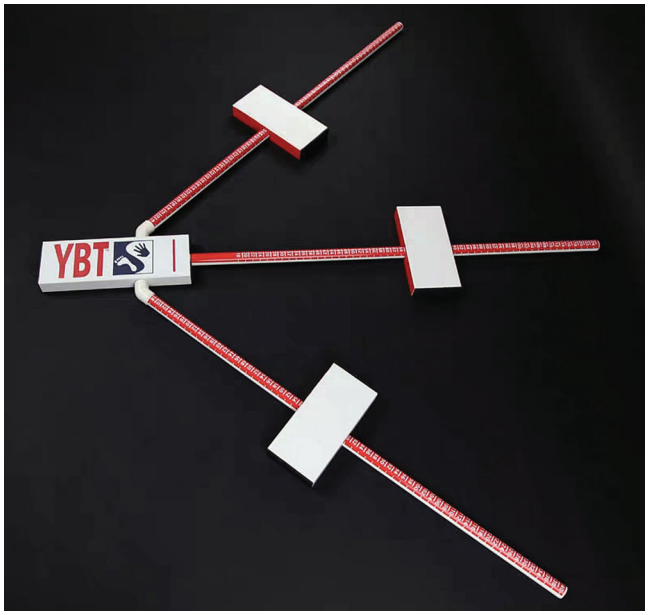

Figure 3: YBT kit

At the end of the experiment, the Italian Free Step plantar pressure testing system was used to test the plantar pressure of two groups of athletes in different standing positions. The athlete stood in the test area with their feet naturally apart and their hands naturally down. The standing positions collected included:

① standing on two legs with eyes closed;

② standing on two legs with eyes open;

③ standing on the left leg with eyes closed;

④ standing on the left leg with eyes open;

⑤ standing on the right leg with eyes closed;

⑥ standing on the right leg with eyes open.

Each standing posture was kept for 2 min, and the test interval was 1 min. The free step system evaluated the human standing posture by parameters such as the change in the trajectory of the center of gravity and the X/Y axis offset distance. The test parameters selected in this paper included:

① total length of the trajectory of movement (TTW): the total length of movement of the center of gravity of plantar pressure from the beginning to the end;

② envelope curve ellipse area (EA): the area of the region enveloping 95% of the trajectory of the pressure center of gravity;

③ the maximum displacement in the left and right direction (Delta X): the distance that the center of gravity of the plantar pressure moves in the left and right direction when the human body is standing;

④ the maximum displacement in the anterior-posterior direction (Delta Y): the distance that the center of gravity of plantar pressure moves in the anterior-posterior direction when the human body is standing.

The smaller the above values, the better the body center of gravity, i.e., the better the body balance control.

2.4 Statistical Analysis

Experimental data were processed using SPSS 21.0 software. Data were recorded in the form of $x \pm sd$. Repeated-measures analysis of variance was used. Differences between groups were tested by independent samples *t*-test, and comparisons within groups were made using paired samples *t*-test. The significance level was set at 0.05. If $p < 0.05$, it means that the difference is significant; if $p < 0.01$, it means that the difference is very significant. The graphs were plotted in Excel to show the experimental results.

3 Study Results

3.1 Comparison of Results of Standing on One Foot with Eyes Closed

First, before and after the experiment, the comparison of the two groups standing on one leg with eyes closed is shown in Fig. 4.

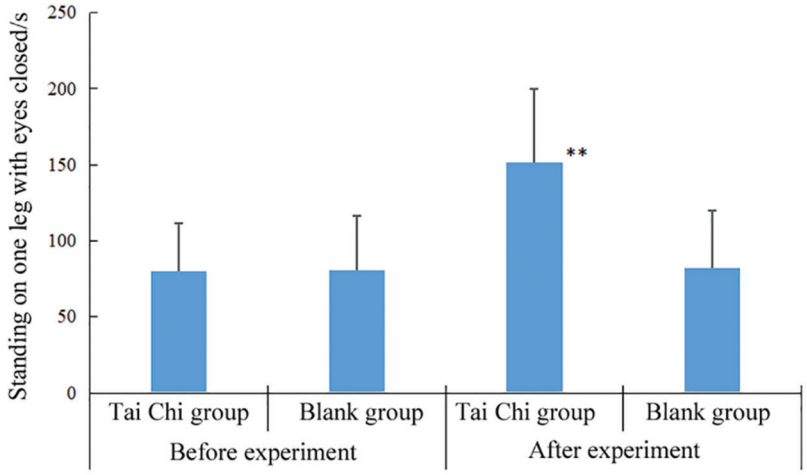

Figure 4: Comparison of standing on one foot with eyes closed before and after the experiment
Note: $^{**}p < 0.01$.

As shown in Fig. 4, before the experiment, there was no significant difference between the performance of the two groups in standing on one leg with eyes closed ($p < 0.05$). It proved that the practice of Tai Chi (eight methods and five steps) had an improvement effect on the athletes' performance in standing on one leg with eyes closed.

3.2 Comparison of Results of YBT Test Score

The YBT scores of the two groups before and after the experiment are shown in Tables 2 and 3.

From Table 2, after the experiment, the YBT score of the left side of the Tai Chi group was 101.84 ± 5.97 ($p < 0.05$ compared to 96.12 ± 7.33 before the experiment); after the experiment, the YBT score of the right side of the Tai Chi group was 100.59 ± 5.66 ($p < 0.05$ compared to 97.64 ± 8.12 before the experiment. However, the YBT scores of the blank group before and after the experiment showed no significant difference. The analysis of the effect size (Table 3) revealed a significance level (sig) of 0.021 for the training method, indicating a statistically significant difference. The results indicated that the practice of Tai Chi could effectively improve YBT scores.

3.3 Comparison of Planar Pressure Test System Results

After the experiment, the test results of the body balance control ability of the two groups when standing on two legs with eyes closed/open are shown in Table 4.

Table 2: Comparison of YBT scores between the two groups before and after the experiment

		Left side	Right side
Tai Chi group	Pre-experiment	96.12 ± 7.33	97.64 ± 8.12
	After the experiment	101.84 ± 5.97*	100.59 ± 5.66*
p value		0.027	0.026
Blank group	Pre-experiment	98.99 ± 5.56	97.44 ± 7.07
	After the experiment	99.37 ± 6.12	98.56 ± 6.32
p value		0.067	0.084

Note: $^{*}p < 0.05$.

Table 3: Results of effect size analysis

Source	F	Sig	Partial η^2
Test time	2.215	0.125	0.521
Training time	5.412	0.021	0.252
Left and right limbs	1.524	0.384	0.476

Table 4: Comparison of body balance control ability when standing on two legs with eyes closed/open

		TTW/mm	EA/mm^2	Delta X/mm	Delta Y/mm
Eyes closed	Tai Chi group	1204.59 ± 50.36	23.46 ± 6.86**	7.64 ± 1.03*	5.88 ± 0.75*
	Blank group	1162.54 ± 49.67	55.64 ± 7.98	12.21 ± 1.27	8.97 ± 0.86
p value		0.318	0.007	0.025	0.021
Eyes open	Tai Chi group	1168.77 ± 62.33	27.64 ± 6.73*	7.31 ± 0.56*	6.56 ± 0.88
	Blank group	1177.45 ± 58.46	40.66 ± 5.84	9.87 ± 0.84	7.62 ± 0.72
p value		0.526	0.027	0.016	0.258

Note: $^{*}p < 0.05$; $^{**}p < 0.01$.

As shown in Table 4, when standing on both legs with eyes closed, differences in EA, Delta X, and Delta Y between the Tai Chi group and the blank group had statistical significance ($p < 0.05$); when standing on both legs with eyes opened, significant differences also existed in EA and Delta X ($p < 0.05$), and the difference in Delta Y had no statistical significance ($p > 0.05$). The effect size analysis results (Table 5) showed that the sig of the training method was 0.022, i.e., showing a significant difference, i.e., Tai Chi practices could effectively improve body balance control ability.

Table 5: Results of effect size analysis

Source	F	Sig	Partial η^2
Training method	4.521	0.022	0.267
Eyes close/open	1.256	0.521	0.245

After the experiment, the test results of the body balance control ability of the two groups when standing on one leg with eyes closed/open are shown in Table 6.

Table 6: Comparison of body balance control ability when standing on one leg with eyes closed/open

Left foot		TTW/mm	EA/mm^2	Delta X/mm	Delta Y/mm
Eyes closed	Tai Chi group	676.27 ± 29.51	1257.37 ± 256.69	30.67 ± 5.12	40.95 ± 3.68
	Blank group	712.09 ± 30.33	1526.77 ± 286.77	35.67 ± 8.71	40.31 ± 3.82
p value		0.674	0.875	0.256	0.352
Eyes open	Tai Chi group	367.56 ± 15.98	482.68 ± 212.36	16.76 ± 4.21	21.36 ± 1.29
	Blank group	371.22 ± 14.62	567.23 ± 212.59	18.67 ± 4.18	20.75 ± 1.34
p value		0.526	0.236	0.412	0.325
Right Foot		TTW/mm	EA/mm^2	Delta X/mm	Delta Y/mm
Eyes closed	Tai Chi group	755.64 ± 38.46	2158.64 ± 564.23	44.36 ± 10.12	52.71 ± 5.19
	Blank group	763.24 ± 40.22	2561.27 ± 601.23	47.88 ± 10.27	53.66 ± 4.27
Eyes open	Tai Chi group	478.69 ± 9.87	312.66 ± 30.12	16.77 ± 0.77	19.85 ± 1.21
	Blank group	466.28 ± 8.99	321.32 ± 29.87	16.12 ± 0.76	19.83 ± 1.11
p value		0.852	0.874	0.258	0.452

From Table 6, all the values in the eyes-closed state were significantly greater than those in the eyes-open state in both groups, which indicated that the athletes' body balance control was poor in the visually restricted state. However, the comparison of TTW, EA, Delta X, and Delta Y between the two groups did not show significant differences when they stood on one leg with eyes closed/open ($p > 0.05$). The results of effect size analysis (Table 7) suggested that the difference had no statistical significance.

Table 7: Results of effect size analysis

Source	F	Sig	Partial η^2
Training method	2.456	0.258	0.521
Eyes close/open	1.258	0.364	0.452
Left and right limbs	1.826	0.247	0.258

4 Discussion

Tai Chi, as a traditional martial art, has been shown to improve anxiety in the elderly [25], alleviate sleep disorders [26], improve sleep quality in adults [27], improve cardiorespiratory function and quality of life [28], etc. However, most of the research on Tai Chi has focused on middle-aged and elderly people, patients with injuries and diseases, while there are fewer studies on athletes. In order to understand the impact of Tai Chi practice on athletes, this study focused on athletes' ability to control body balance. After a 9-week experiment, it was found that practicing Tai Chi (eight methods and five steps) had a positive effect on improving athletes balance control ability. It enhanced their performance in the closed-eye single-leg standing test and their YBT scores. In the plantar pressure test, although there was no significant difference between the body balance control ability of the two groups of athletes when they

stood on one leg with eyes closed/open ($p > 0.05$), the EA of the Tai Chi group was 23.46 ± 6.86 mm^2 when the athletes stood on two legs with eyes closed ($p < 0.01$ compared with the blank group), and the Delta X and Delta Y results of the two groups showed significant differences ($p < 0.05$). When they stood on both legs with their eyes open, the EA and Delta X of the Tai Chi group were also significantly different from those of the blank group ($p < 0.05$). This suggested that the Tai Chi group effectively controlled the body's center of gravity, maintained a stable stance with greater strength, and exhibited better control over bodily shaking, further proving that the practice of Tai Chi could improve the athletes' ability to control their balance.

The balance control ability of the body is related to the function of nerves, muscles and bones [29], and the improvement of various functions of the body has a certain promoting effect on the balance control ability of the body. The eight methods and five steps of Tai Chi are simple and easy to practice, which makes it more convenient to learn and promote Tai Chi. The movements of the eight methods and five steps are relatively slow. In particular, the movements of the lower limbs are relatively stable, and the center of gravity moves slowly. A series of slow movements are conducive to improving limb coordination. The eight methods and five steps movements also require a certain level of muscle strength. In the process of continuous practice, athletes promote blood circulation and gradually improve the strength of the joints in their lower limbs. In addition, the continuous change in body form during slow movement gradually improves the flexibility and stability of athletes' ankle joints. The stability of the ankle joint is closely related to the body's ability to control its balance [30], so the athlete's ability to control the body's balance is also improved. Compared to current research findings, this study demonstrates the role of practicing Tai Chi (eight methods and five steps) in improving athletes' ability to control their body balance, providing support for the application of Tai Chi in athlete training. Compared to current research findings, this study demonstrates the role of practicing Tai Chi (eight methods and five steps) in improving athletes' ability to control their body balance, providing support for the application of Tai Chi in athlete training.

All the study results showed that the practice of Tai Chi (eight methods and five steps) can effectively improve athletes' ability to control body balance. Since Tai Chi is a relaxing exercise, the risk of sports injuries is also low. Therefore, the practice of Tai Chi can be added to the daily training of athletes to help them better improve their body balance control ability.

5 Conclusion

In this paper, the effect of Tai Chi (eight methods and five steps) on the body balance control of athletes was investigated mainly from a biomechanical perspective. Through a nine-week experiment on 20 athletes, it was found that the practice of Tai Chi (eight methods and five steps) could effectively prolong the duration of single-leg standing with eyes closed and increase the YBT score. Additionally, it was observed that Tai Chi also reduced EA, Delta X, and Delta Y values, and these values were significantly different from those of the blank group. The experimental results show that practicing Tai Chi (eight methods and five steps) can improve athletes' ability to control body balance, making it applicable to their actual training.

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Availability of Data and Materials: The data and materials are available from the author upon reasonable request.

Conflicts of Interest: The author declares that she has no conflicts of interest to report regarding the present study.

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