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Article

Evaluation of the effect of artificial intelligence training equipment in physical training of table tennis players from a biomechanical perspective

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Abstract: In table tennis competitions, the movement data of table tennis players plays an important role in daily training. In recent years, artificial intelligence technology has been widely used in sports competitions. With the development of artificial intelligence, how to use artificial intelligence to analyze sports video to obtain sports data of athletes has become more and more important. This paper is to use artificial intelligence to research and analyze the athletes in the table tennis competition, and then obtain the sports data of the athletes. This has important guiding significance for athletes and coaches in their daily training. Table tennis is a widely developed sport in China, and as China's "national ball", table tennis has always been in a leading position in the world table tennis competitions. It is widely loved by the public for its simple and easy access to sports facilities, low site requirements and sports methods. In this study, mathematical statistics and experimental methods were used. Combined with the application of the functional sports screen function test, 20 table tennis players from Shandong Sport University were selected as the test objects, and their sports performance was tested. The total score of 10 first-level athletes was 162 points, and the average score was 16.2 points. The total score of the 10 second-level athletes was 144 points, and the average score was 14.4 points. The performance of the first-level athletes was significantly higher than that of the second-level athletes. It showed that the first-level athletes were generally better than the second-level athletes in all aspects.

Keywords: functional screening; table tennis players; athletic ability; physical training; evaluation diagnosis

1. Introduction

The development of artificial intelligence and computer vision technology has brought great changes to people's lives. The 2018 World Cup used a number of emerging electronic intelligent equipment. This has attracted the attention of many spectators. For example, in the World Cup group stage, Australia used a VAR video technology to help referees make decisions. American basketball players used the SportVU system to count each player's distance traveled, time with the ball, and the number of passes during the game. The Hawkeye system used in tennis matches. In a round, when a ball belongs to the in-bounds or out-of-bounds dispute, the players and coaches can appeal the referee's penalty by watching the "hawk-eye system". Through the eagle eye system, it is very clear whether the landing point of the ball is in or out of bounds. In traditional sports games, the single viewing form of TV broadcast and network video can meet the simple needs of fans. However, for coaches and athletes, the single method of reviewing video footage can no longer satisfy athletes and coaches in formulating tactics and predicting games. With the rapid development of deep learning, intelligent analysis of traditional game videos has become more and more necessary.

Table tennis is a national game. In recent decades, Chinese athletes have won countless honors for the motherland. Practice has proved that in the 21st century Olympic Games and world competitions, computer technology would play an increasingly important role, which affects the results of sports competitions to a certain extent. However, compared with western developed countries, China's level of sports technology still lags behind western countries. In particular, tools for video analysis of sports games are lacking. The video clips of traditional table tennis game highlights are collected by multiple cameras at the game site and played through post-editing. This method can basically meet the needs of table tennis fans. However, for athletes and coaches, if they can know the sports data of athletes, it is of great practical significance for them to analyze the actual data and improve the quality of daily training.

In the field of table tennis, China has always had outstanding advantages in this aspect, which has led many people to study this aspect such as: Wang J proposed an established second-order mixed Markov chain hybrid model to describe and simulate the process of table tennis matches. Compared to existing methods, its method was the first to support efficient simulated tactics, representing a high level of game strategy in table tennis. In addition, he also introduced a visual analysis system named Tac-Simur based on the proposed visual analysis simulation model [1]. Hayashi I proposed the Terrain Attention Mapping (TAM) network as a biologically inspired classifier with similarities to the human visual system. A TAM network was used to extract input attributes and technical rules to classify the skill level of table tennis players from sensor data [2]. Iino used OpenSim's static optimization algorithm to estimate the activation patterns of lower extremity muscles. The simulation was repeated with the maximum isometric force or maximum shortening velocity of each muscle group changed by ±10% of their original value. The results suggested that increasing the maximum isometric force of the hip extensors and adductors may be most effective in reducing muscle strength [3]. Cf A conducted a literature review through a systematic search of three scientific databases. Overall, table tennis physiology was complex because of intensity and intermittent effort. It was found that neurophysiological findings tended to define table tennis as an anticipatory movement rather than a reactive movement, and higher than average eye movement skills were found in the table tennis population [4]. Li Y M investigated the feasibility of applying energy cost measures widely used in cycling to multi-ball practice in table tennis. Ten members of a university table tennis team participated in a treadmill graded exercise load test and a two-stage test. All three trials used portable spirometer systems and heart rate monitors. Earlobe blood samples were collected and analyzed before and after the test [5]. This is a sport affected by many aspects, and there are still various problems in the research of this sport.

Athletes' bodies are studied in a very effective way: the Ellison M study aimed to validate previous findings in international elite youth table tennis players to elucidate the prevalence of neural performance determinants across sports and age groups with different visual motor requirements [6]. The purpose of Yan's study was to investigate the effect of performance levels on lower extremity kinematics in the table tennis forehand cycle. 13 male Senior Players (SP) and 13 Intermediate Players (IP) participated in this test. Compared to IP, SP exhibited greater hip flexion and knee external rotation at the posterior end and greater hip internal rotation and extension at the anterior end [7]. A univariate Analysis of Variance (ANOVA) of tennis players versus football players, other sports players, and non-athletes in the nine-sport test proposed by Siener M showed that table tennis players significantly outperformed other sports groups in the test tasks of side jumps and push-ups [8]. The purpose of Yoichi was to evaluate the relationship between the changing structure of the torso and racket arm joint angles in table tennis forehand topspin and the control of racket orientation using an Uncontrolled Manifold (UCM) method. Experiments showed that the redundancy utilization was the highest when hitting the ball, and this result may reflect that the table tennis forehand was a fast interception task [9]. The purpose of Xia R was to compare the joint, racket, and ball kinematics of backhand and straight shots in table tennis forehand and backhand by senior male athletes. Research has shown that the racket angle was calculated as the relative movement of the racket to the forearm. For forehand shots, there was no significant difference in ball or racket speed between the two grips. The handshake grip tended to exhibit a greater external rotation angle of the shoulder compared to the straight grip [10]. It was not enough to just analyze the player data of table tennis players, but also to conduct in-depth research on the movements of the players.

The innovation of this paper is to expound the theoretical basis of the Kalman filter algorithm. On this basis, the idea and implementation principle of the standard Kalman Filter algorithm (KF) were studied in detail, and the Kalman tracking model suitable for table tennis players in this paper was established. Five video of table tennis matches selected from the Internet were used as the test data set for testing, and the performance of the standard Kalman filter algorithm was finally analyzed.

2. Evaluation of physical fitness training of table tennis players

2.1. Table tennis player training program

The research technology route is shown in **Figure 1**:

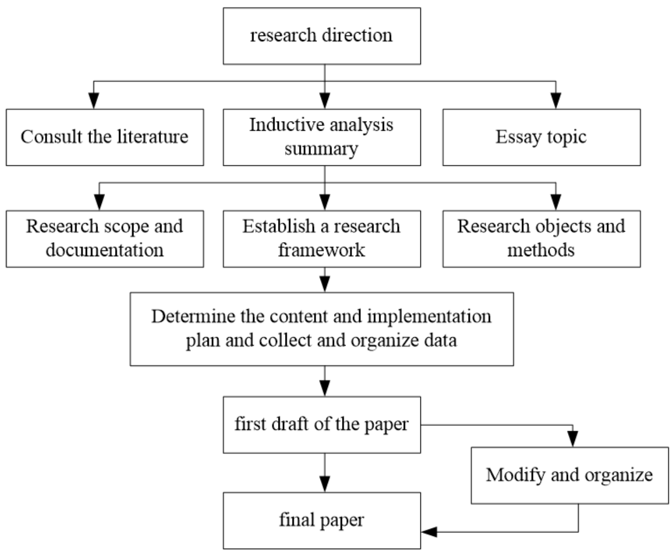

Figure 1. Technology route.

As can be seen from **Figure 1**, according to the tests carried out on the sports function screening of professional table tennis athletes and the final scores obtained, the "threshold" of possible sports injuries in athletes should be found, and various actions that are closely related to sports injuries should also be found. Through a comprehensive test of the athlete's movement screening, combined with the final score, corrective intervention is carried out in time [11]. A complete set of corrective exercise design plans are provided, including tests, evaluations, and corrective procedures for motor function screening. It is only for reference and reference by sports groups of table tennis or other sports.

The structure of the athlete's physical fitness system is shown in **Figure 2**:

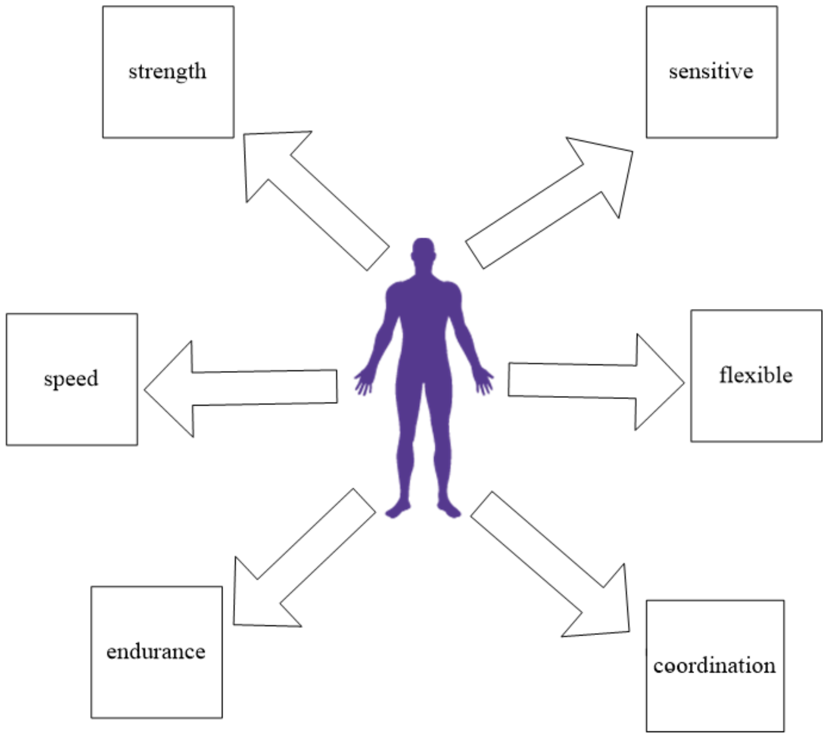

Figure 2. Structure of the athlete's physical fitness system.

It can be seen from **Figure 2** that the composition of physical fitness is composed of these six sports elements, which is in line with the definition category in the Chinese textbook "Sports Training".

Most of the experimental subjects in this study are in the period of sudden height increase. According to the adolescent body development model, the increase of muscle mass, the development of motor skills and the training of physical flexibility would become the core content at this stage, and the adaptation to the training is mainly based on the joint adaptation of the endocrine system and the nervous system. Based on the above conclusions, a youth physical development strategy is formulated, as shown in **Figure 3**:

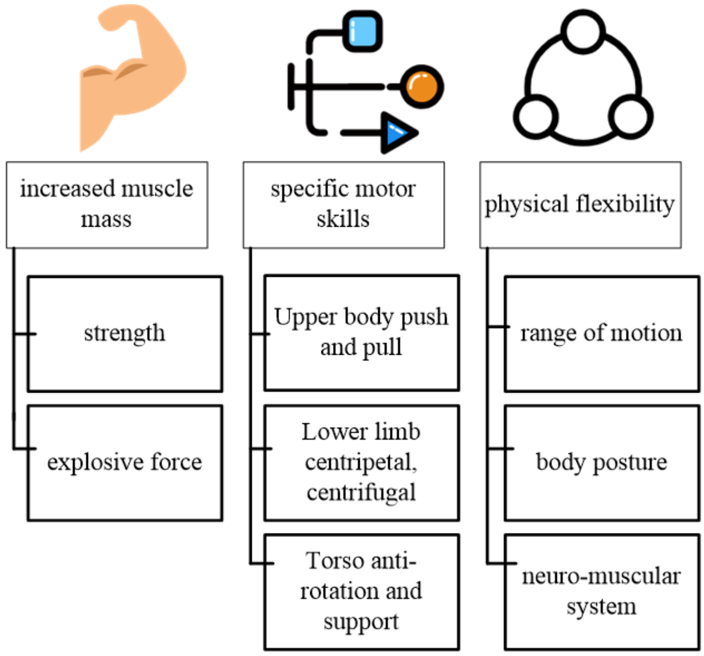

Figure 3. Adolescent physical development strategies.

It can be seen from **Figure 3** that the strength training of trunk pillars is based on improving the flexibility and stability of each joint, and develops the strength of the shoulder, spine, lumbar and hip. From the basic action mode training to the special action mode training, the coordination of the neuro-muscular system is gradually improved, so as to develop the special explosive power of table tennis.

The 12-week trunk strut strength training is divided into 3 phases. The first stage focuses on improving the flexibility and stability of joints and mastering motor skills. The second stage is mainly to develop strength and improve the control ability of nerves to muscles. The third stage is mainly to improve the explosive power [12]. The structure of each training session is shown in **Figure 4**.

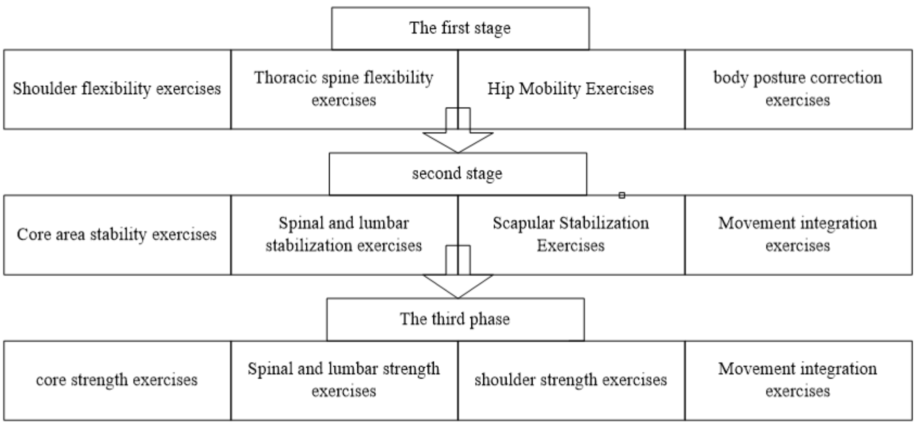

Figure 4. Training structure.

As can be seen from **Figure 4**, through the analysis of the FMS (Functional Movement Screen) test results, it is found that the subjects generally have limited flexibility of the thoracic spine, hip joint and shoulder joint. The injury prevention session mainly focuses on targeted exercises for shoulder flexibility, scapular stability, and thoracic spine flexibility. Through the rolling of the thoracic spine and the rotation of the kneeling thoracic spine by the foam sleeve, the flexibility of the thoracic spine is increased. The occurrence of shoulder injury is related to insufficient rotator cuff muscle strength, limited range of motion of the shoulder joint, and insufficient scapula stability. In the shoulder joint injury prevention part, the shoulder joint abduction action is performed on the side to increase its flexibility. On this basis, the full range of motion and stability of the scapula can be improved through scapula push-ups, and the occurrence of shoulder joint injuries can be reduced through strength exercises of the rotator cuff muscles [13].

In the core training content, a side-step squat action similar to the lateral movement of a table tennis ball is arranged in the pelvis and buttocks. Through the improvement of single-leg strength, sports performance can be improved and sports injuries can be prevented. In the process of single-leg squatting, it is necessary to mobilize the stable muscles of the pelvis and the spine to participate in the movement. These include gluteus medius, adductors, quadratus lumborum, erector spinae, multifidus, etc., which help to improve the control ability of nerves over muscles while developing muscle strength [14]. In terms of strength in the shoulder area, it includes equal amounts of horizontal pulling and horizontal pushing. The action of upper body push mainly develops the muscle strength of the front side chain of the body, which is similar to the force characteristics of table tennis. The upper limb pulling action avoids the imbalance of shoulder strength caused by training, which increases the risk of sports injury. The muscle group used in the standing horizontal pull action is the antagonist muscle of the push-up action, and at the same time, the hip joint is stabilized by the rotation muscle group of the hip. This is similar to the power transmission in table tennis. The force on the ground needs to be transmitted to the upper limbs through a stable hip joint to increase the transmission efficiency of the power chain. On the basis of mastering the horizontal pulling action pattern in the basic stance state, it is gradually advanced to a rotating horizontal pull similar to the special action mode of table tennis. During the movement, it not only develops the stability of the rear side chain of the body, but also improves the muscle strength of the middle and lower part of the trapezius muscle, and corrects the phenomenon of round shoulders and hunchback caused by the imbalance of upper limb muscle strength [15]. The medicine ball squat lift improves hip mobility and full range of motion. Through the sagittal movement of the hip joint, the force is transmitted to the arm, and the upward force direction can improve the strength of the body on the side chain. At the same time, the stabilizing muscles of the spine are used as the guarantee of efficient power transmission, so that athletes can experience the process of force generation and force transmission in the hip joint. A stable neutral position of the spine is very important, which is similar to the energy transmission process in table tennis.

Today’s table tennis project is developing towards a higher level and extreme value, and the gap between high-level players’ skills and tactics is getting smaller and smaller. According to the reasoning of the research results of modern training concepts, the athletes’ physical fitness level, technical and tactical ability, and psychological ability form a unified overall relationship, and are also divided into independent “small system” energies. They present a multi-dimensional pyramid model. The main factors that affect the results of the game are as follows: high level of physical reserve → strength-based physical conditions suitable for the development of the current table tennis project → the level of technical and tactical ability to master the world's most advanced speed, strength, and rotation characteristics → the psychological qualities of high intensity, high density, high confrontation, and multiple rounds of table tennis [16]. It can be seen from this that the winning result = strong physical function level + perfect technical and tactical level + excellent psychological adjustment level.

Therefore, starting from the objectivity of relevant data and evaluation, the selection of outstanding reserve talents through psychological quality is an indispensable and important link in the youth table tennis training system. Together with the physical fitness and technical and tactical evaluation system, it constitutes a complete training evaluation system for youth table tennis [17,18]. The architecture of physical fitness, technical tactics, and psychological integration is shown in **Figure 5**.

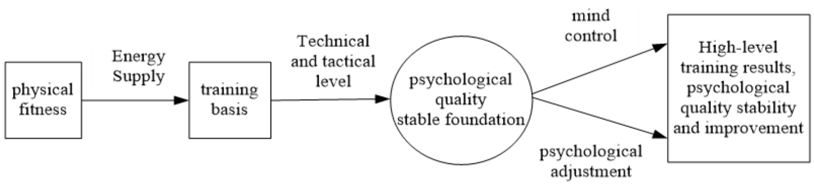

Figure 5. Architecture of physical, technical and tactical integration.

It can be seen from **Figure 5** that the psychological quality, good physical fitness (physical function) state, and the formation of techniques and tactics (the basic training stage of young table tennis players) have been accompanied by long-term systematic training and have been steadily improved. In the end, it forms a manifestation of the stability and excellent psychological quality of young table tennis players [19]. At the same time, it is also necessary to see that psychological factors are related to the influence of various factors such as training foundation, environmental changes, coaches' teaching level, and competition practice activities. This requires an organic and comprehensive analysis of the psychological quality training, self-regulation ability and physical reserve, and technical and tactical formation of young table tennis players and runs through the whole process of material selection. In the process of psychological selection, the effective expression of the psychological state of young table tennis players based on relevant objective data is used as a scientific basis to solve the problem of judgment by subjective factors and lack of objective basis.

2.2. Standard kalman filter algorithm

The Kalman filtering algorithm used in this article is innovative compared to existing technologies in that it can effectively predict the movement state of table tennis players and improve prediction accuracy by optimizing formula parameters. At the same time, the algorithm combines principles of biomechanics, providing a more scientific basis and more accurate training guidance for the physical fitness training of table tennis players. The standard Kalman Filter (KF) algorithm can effectively predict the position of the target. By establishing a state formula, the observation data is input into the state, and the parameters of the formula are optimized. The position of the object in the nth frame can be effectively predicted by inputting the data of the first n frames [20].

The state formula and observation formula are shown in Equations (1) and (2), respectively

$$y_i = A_i y_{i-1} + u_i \tag{1}$$

$$Z_i = H_i y_i + v_i \tag{2}$$

The specific process of the algorithm is as follows.

The system state prediction is:

$$\hat{y}_{i|i-1} = A_i \hat{x}_{i-1} \tag{3}$$

The prediction prior error covariance matrix is:

$$P_{i|i-1} = A_i p_{i-1|i-1} A_i^T + W_i \tag{4}$$

The Kalman gain matrix is calculated:

$$I_i = P_{i|i-1} H_i^T \left(H_i P_{i|i-1} H_i^T + R_i \right)^{-1} \tag{5}$$

System status is updated:

$$\hat{y}_{i|i} = \hat{y}_{i|i-1} + I_i (Z_i - H_i \hat{y}_{i|i-1}) \tag{6}$$

The updated posterior error covariance matrix is:

$$P_i = (K - I_i H_i) P_{i|i-1} \tag{7}$$

The table tennis player to be observed establishes a player state model, and sets two variables *p* and *v*. *G* is the control input model.

$$P_i = P_{i-1} + (t_i - t_{i-1}) v_{i-1} + \frac{1}{2} a_i (t_i - t_{i-1})^2 \tag{8}$$

$$v_i = v_{i-1} + (t_i - t_{i-1}) a_i \tag{9}$$

If $(t_i - t_{i-1}) = \Delta t$, then:

$$P_i = P_{i-1} + \Delta t \times v_{i-1} + \frac{1}{2} a_i (\Delta t)^2 \tag{10}$$

$$v_i = v_{i-1} + \Delta t \times a_i \tag{11}$$

The state transition form is:

$$y_i = F_i y_i + G_i a_i \tag{12}$$

Among them, F_i, G_i is represented in matrix form as:

$$y_i = F_i y_i + \begin{bmatrix} \frac{\Delta t^2}{2} \\ \Delta t \end{bmatrix} a_i = F_i \times y_{i-1} + G_i \times u_i + w_i \tag{13}$$

In Equation (13), u is the control vector, that is, a. By adding the covariance matrix W to deal with the noise, the extended covariance is obtained as shown in Equation (14).

$$P_{i|i-1} = F_i P_{i-1|i-1} F_i^T + W_i \tag{14}$$

The target detection algorithm predicts that the height of the box is h and the width is w, then:

$$h_1 = x_{12} - x_{11} \tag{15}$$

$$w_i = y_{12} - y_{11} \tag{16}$$

The width of the artificially marked real box is w, and the height is h, then:

$$w_2 = y_{22} - y_{21} \tag{17}$$

$$h_2 = x_{22} - x_{21} \tag{18}$$

The target detection algorithm predicts the box and the human-marked real box with a width of w and a height of h, then:

$$w = w_2 + w_1 - (y_{22} - y_{11}) \tag{19}$$

$$h = h_2 + h_1 - (x_{22} - x_{11}) \tag{20}$$

Then there are:

$$IOU = \frac{w \times h}{w_2 \times h_2 - w \times h + w_1 \times h_1} \tag{21}$$

3. Physical training experiment of table tennis players

3.1. Experimental method

This study carefully selected 100 middle school table tennis athletes aged 10 to 16, ensuring that they have at least one year of table tennis training experience, are physically healthy, have no major injuries, and are capable of high-intensity physical training. At the same time, 20 college athletes from Shandong Sport University were also selected, who were classified into first and second level according to their sports level for more in-depth comparative analysis [21].

In terms of training plan, this article sets a training frequency of three times a week, each lasting 40 to 50 min, for 12 weeks. The training content covers multiple aspects such as improving joint flexibility, stability, and strength, gradually transitioning from basic movements to specialized movements to comprehensively enhance the physical fitness level of athletes. In addition, variables such as training time, intensity, and coach guidance were strictly controlled during the training process to ensure the reliability and reproducibility of the experimental results.as shown in **Figure 6**.

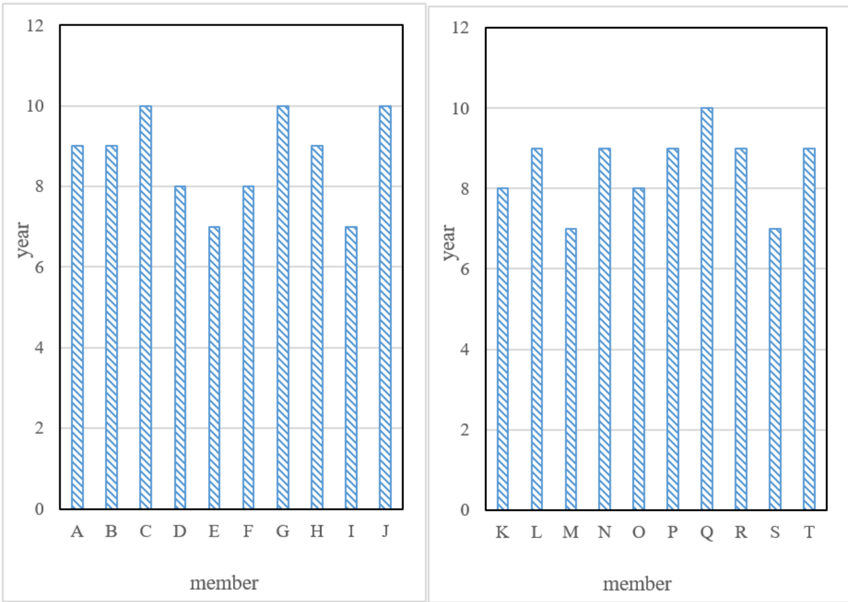

Figure 6. Basic information of 20 college athletes. **(a)** Group A male table tennis players. **(b)** Group B female table tennis players.

It can be seen from **Figure 6** that **Figure 6a** is the training years of the first-level athletes, and **Figure 6b** is the training years of the second-level athletes. In this study, various frontal data of 20 table tennis players are analyzed. Combined with expert interviews, a trunk support strength training program that meets the characteristics of the group is formulated, and a 1-week pre-experiment is conducted. The experimental plan and training methods are adjusted in a targeted manner. Through the training of 40–50 min each time and 3 times a week for 12 weeks, the data changes before and after the experiment are compared and analyzed, and the influence of trunk support strength training in unit time on the training effect of middle school table tennis players is discussed.

3.2. General situation of functional movement screening

In order to improve the authenticity and validity of this study, the functional movements of table tennis players in the second middle school are tested. The details are as follows: a functional screening test is carried out for the selected 10 subjects. In this screening test, each movement is tested three times on the left and right sides (excluding the squat test and the trunk stability push-up test), and the final test result is the unilateral minimum. Then the test results are counted, and the test results are entered in Excel software to calculate their mean and standard deviation. The specific results are shown in **Table 1**.

It can be seen from **Table 1** that the main low-scoring items are mainly concentrated on shoulder joint flexibility, trunk stability and rotational stability. According to the actual situation and this data, the appearance of such a low score is due to the characteristics of the table tennis players' own movement, and low-scoring items mostly appear on the lower limbs and half of the torso in daily table tennis training.

Table 1. Functional movement screening FMS total test form.

Tested sequence	overhead squats	hurdle step	Straight lunge squat	shoulder flexibility	Active straight knee lift	Dry out stability	rotational stability	total
1	2	1	2	3	2	1	1	12
2	3	3	1	2	1	2	1	13
3	2	3	2	3	3	1	2	16
4	3	3	2	3	3	2	1	17
5	3	2	2	2	3	1	3	16
6	2	3	2	2	3	2	1	15
7	2	3	2	1	1	1	2	12
8	3	3	3	1	1	2	1	14
9	0	3	0	1	2	0	0	6
10	2	2	1	2	3	1	2	13

Sports level is the most direct definition of an athlete's level, and it is also a direct reflection of the physical and mental abilities of athletes. Therefore, when an athlete's physical function and mental ability are the best, it is often the moment when an athlete's level is at its peak. Athletes at different levels also represent different motor functions. In the process of functional testing, athletes at different levels have different motor functions and specific test scores. However, even this does not mean that athletes with higher athletic levels would have better performance scores on relevant functional tests. In the process of this research, the 20 athletes who would be tested in this paper have different grades of undergraduate and master's degree. Among them, there are first-level and second-level athletes in the undergraduate degree, and second-level athletes in the master's degree. Therefore, its specific functional test is shown in **Figure 7**:

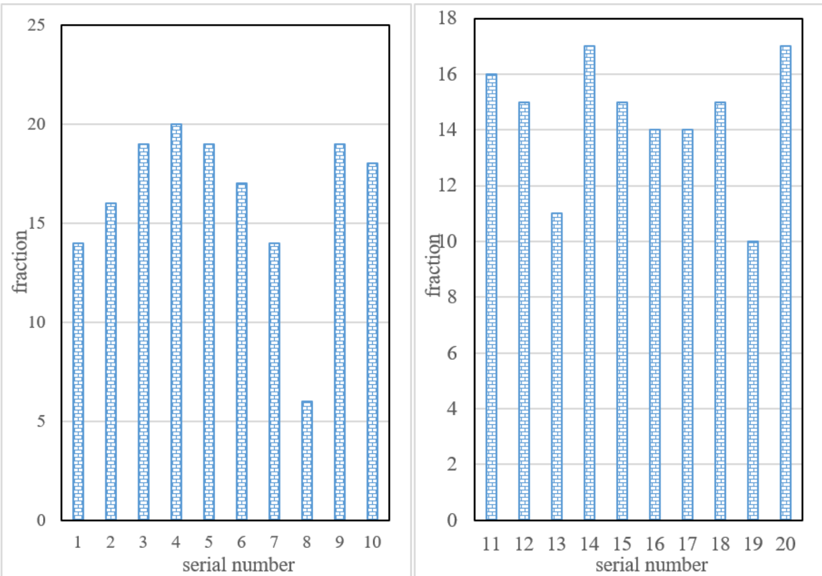

Figure 7. Functional movement test FMS athlete test chart. **(a)** Test chart for first-level athletes. **(b)** Test chart for second-level athletes.

In this study, the average test scores in **Figure 7a** are higher than those in **Figure 7b**. The total and average scores of the 10 first-level athletes are 162 and 16.2, respectively. The total score and average score of the 10 first-level athletes are 144 and 14.4 points, respectively. The maximum score of the postgraduate level 1 table tennis player test is 20 points and the minimum score is 6 points. The maximum score of the postgraduate second-level table tennis player test is 17 points and the minimum score is 10 points. The scores of the second-level master's athletes are relatively concentrated. This is because the master's second-level athletes can better master scientific and standardized training after experiencing relevant high-level theoretical study and long-term training practice, so as to effectively improve and maintain their own physical function. Therefore, the performance distribution of the 20 athletes tested in **Figure 7** is relatively concentrated, and there are few low scores. Athletes of different levels can affect scores on specific test items. For example, there is a large difference in scores in the squat test, active straight knee lift, and trunk stability push-up.

3.3. Evaluation of the effect of trunk pillar training on the functional movement level of table tennis players in middle school students

In the 7 FMS test actions, the test scores were significantly improved as shown in **Figure 8**:

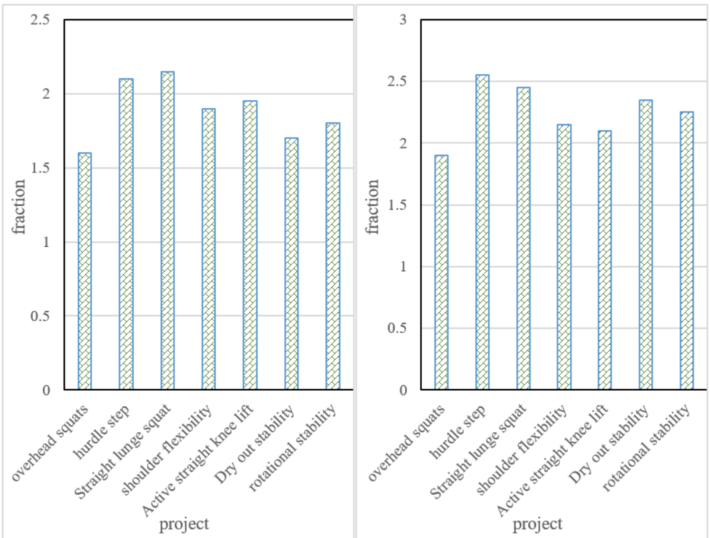

Figure 8. FMS score.

It can be seen from **Figure 8** that the average score of the shoulder joint flexibility extension test is analyzed in combination with the left and right figures of **Figure 8** and the average score is increased by 0.25. The lateral shoulder rotation in the training protocol improves the subject's shoulder mobility. This test mainly reflects the stability of the core muscles and the strength of the upper limbs of the subjects. Through the practice of eccentric push-up in an unstable state, the subjects enhances the stability of the core muscle group in the sagittal plane. The shoulder stabilizer muscle group belongs to the deep muscle group and is not easy to be mobilized. In the eccentric stage of push-up descent, this part of the stable muscle group is mainly eccentric and combined with isometric contractions, which improves the stability of the shoulder joint while developing the strength of the subjects' upper limbs. Rotator cuff muscles play an important role in preventing shoulder joint injuries (such as acromion impingement syndrome, rotator cuff tear, etc.) as an important stabilizing muscle group during shoulder movement. The strength of the rotator cuff muscles is improved through the double-arm "L" shaped swing exercise, and the stability of the shoulder joint is increased. Through single-leg deadlift + rowing, the strength of the dorsal chain of the body is developed, and the imbalance between the front and rear muscles caused by the long-term special training of table tennis is relieved. Some subjects shows improvement in scapular wing shape, which results in improved trunk stability push-up test scores. Side lying shoulder rotation can effectively improve the level of shoulder joint flexibility. Double-arm "L" swing and eccentric push-ups (non-stable) can effectively improve the level of trunk pillar stability push-ups. Single-leg deadlift + rowing, elastic band rotating horizontal pull can effectively improve the squat test action level. Proprioceptive training and hip and hip strength training can effectively improve the movement level of the hurdle step test.

3.4. Evaluation of functional movement screening scores of athletes with different training years

Years of training is an important factor affecting the physical function of athletes, and it is also a direct factor affecting the score of this functional movement test. Factors such as the length of training time, the length of years, the size of the intensity, the scientificity of the program, the interval between training and rest, and the injuries caused by training would bring the most intuitive changes to the physical function and physical condition of the athlete. The data shown in **Table 2** are about the scores of subjects with different training years on the functional movement screening test. According to the time of the athletes participating in the competition and training, this paper would test the subjects into two training years with a limit of 9 years, namely below the ninth grade and above the ninth grade. With the help of Excel software, data analysis is carried out on the training years of the subjects, and the average and standard deviation of the dependent variables of the FMS test items and total scores are calculated. In order to further analyze whether the differences in functional sports screening tests among table tennis players with different training years are statistically significant, this article proposes to conduct a series of more detailed statistical tests. Firstly, ANOVA (Analysis of Variance) is an effective statistical method that can evaluate whether there are significant mean differences between different groups. In the context of this article, athletes can be divided into two groups based on their training years (such as less than 9 years and more than 9 years), and ANOVA analysis can be conducted on the scores of each FMS test item (such as over the top squat, hurdle step, shoulder flexibility, etc.). Through ANOVA, this article can determine whether there are significant differences in these test items among athletes with different training years.

In addition to ANOVA, t-test is also one of the commonly used statistical methods. For certain specific testing items, if this article suspects that the differences between the two groups may be particularly significant, t-test can be used for further validation. The t-test can directly compare the mean difference between two sets of data and provide a conclusion on whether this difference is statistically significant.

In addition, in order to comprehensively evaluate the validity of the data, this article also needs to pay attention to the p-value. In statistics, the *p*-value represents the probability of an observed result (or more extreme result) appearing in the data. If this probability is low (usually less than 0.05), the observed difference is considered statistically significant. Therefore, after introducing statistical testing, this article needs to ensure that all obtained *p*-values are carefully interpreted and validated to ensure that the conclusions of this article are based on reliable data analysis. The specific results are shown in **Table 2**:

Table 2. Correlation test of test results of athletes with different training years.

	Years of exercise	**mean**	**standard deviation**	***p*-value**
overhead squats	under 9 years	2.03	0.84	0.452
	more than 9 years	2.38	0.93	
hurdle step	under 9 years	2.69	0.85	0.643
	more than 9 years	2.57	0.79	
Straight lunge squat	under 9 years	2.35	0.80	0.534
	more than 9 years	2.26	0.94	
shoulder flexibility	under 9 years	1.82	0.73	0.646
	more than 9 years	1.74	0.78	
Active straight knee lift	under 9 years	2.18	0.79	0.896
	more than 9 years	2.17	0.86	
Dry out stability	under 9 years	2.35	0.77	0.556
	more than 9 years	1.49	0.92	
rotational stability	under 9 years	2.11	0.81	0.536
	more than 9 years	2.23	0.75	
total	under 9 years	15.53	5.59	1.000
	more than 9 years	14.94	5.97	

According to the data in **Table 2**, the difference in training years would affect the differences in the scores of specific specialties. For example, scores vary widely in the overhead squat test, trunk stability push-up, and rotational stability support items.

Because the athletes tested this time have long training years, the relevant test data are more realistic than the athletes' test results in each test. Due to the long-term training, the training habits and movement habits are relatively standard, and the difference in scores is more caused by their respective body functions and physical injuries. Therefore, from the point of view of the overall score, the overall score of the training years above 9 years and 9 years or less is not much different, and the athletes with more than 9 years of training are 0.59 points lower than those with 9 years and below.

In summary, different training years have great differences in stability and flexibility for different athletes. The results of this test show that with increasing age, the stability and flexibility of the athlete show a decrease.

The routine descriptive statistical results of the special physical fitness indicators of Chinese outstanding male and female youth table tennis players reflect the three physical fitness indicators of the tested special physical fitness (side support, lateral sliding touch bar, and reentry). This not only shows the current status of the group's special physical fitness, but also reflects the characteristics of the athletes' special physical fitness indicators, and provides a benchmark value for the following design of the youth table tennis special physical fitness evaluation standard. The physical fitness index test is shown in **Figure 9**:

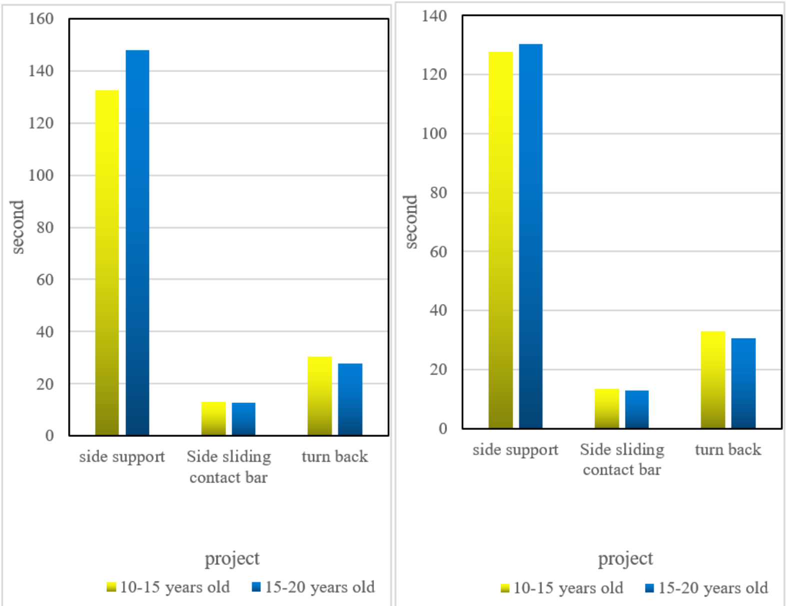

Figure 9. Special physical fitness test for Chinese outstanding table tennis players. **(a)** Special physical fitness test for male teenage table tennis players. **(b)** Special physical fitness test for female teenage table tennis players.

As can be seen from **Figure 9**, the statistical results of each index test of the specific physical fitness of the male youth table tennis players in **Figure 9a** are as follows: the lateral support was 121.85 ± 81.96 seconds and the side sliding contact bar was 13.314 ± 1.3662 seconds, as well as the turn-back was 31.738 ± 2.8716 seconds. In **Figure 9b**, the statistical results of the specific physical fitness indicators of the female and adolescent table tennis players are as follows: the lateral support was 76.77 ± 34.82 seconds and the side sliding contact bar was 13.58 ± 1.3053 seconds, as well as the turn-back was 33.172 ± 2.4177 seconds. The comparison of the special physical fitness indicators of outstanding young table tennis players of different genders is shown in **Table 3**:

Table 3. Comparison results of individual physical fitness indicators of outstanding young table tennis players of different genders (n = 100).

index	gender	number of people	average value
Sitting forward bend(cm)	male	50	27.81
	female	50	22.84
30 s skipping rope(piece)	male	50	76.54
	female	50	58.73
Smash(cm)	male	50	791.35
	female	50	783.83
30 s Crunches(piece)	male	50	25.17
	female	50	26.84
Standing long jump (com)	male	50	185.85
	female	50	174.57

As can be seen from **Table 3**, the comparison results of the specific physical fitness indicators of outstanding young table tennis players of different genders show that there is no significant difference in the indicators of smash hits, second sit-ups, side-sliding bars, and standing long jumps. It shows that the specific explosive force, trunk muscle group strength and lateral sliding movement speed of adolescent table tennis players of different genders are basically the same.

However, there are significant differences in other indicators, and female athletes are significantly lower than male athletes. The difference in the reentry index that also reflects the level of special speed in women is slower than that of men, and the index of skipping rope that reflects the level of special agility is higher than that of men. This may be due to the fact that these two indicators require the participation of lower limb muscles to a certain extent, and the lower limb strength of women is weaker than that of men. **Table 4** shows the specific physical fitness indicators of different ages of outstanding male youth table tennis players:

Table 4. Comparison of different specific physical fitness indicators of male athletes in different age groups (n = 50).

Age index	Sitting forward bend(cm)	30 s skipping rope(piece)	Smash(cm)	30 s Crunches(piece)	Standing long jump (com)
10	25.8	83	760.4	23	137.4
11	26.1	79.2	810.6	24.33	149.3
12	26.2	95.4	815.7	25.11	156.5
13	26.6	101.3	823.5	25.73	159.2
14	27.9	103.1	816.9	26.13	175.3
15	28.1	99.7	821.9	26.21	179.9
16	30.6	102.4	842.1	27.18	181.6

It can be seen from **Table 4** that the comparison results of the special physical fitness indicators of different ages of the outstanding male table tennis players show that with the increase of age, the male athletes have an increasing trend in the level of explosive force and the speed of lateral sliding.

Table 5 shows the special physical fitness indicators of different ages for outstanding female table tennis players:

Table 5. Comparison of different specific physical fitness indicators of female athletes in different age groups (*n* = 50).

Age index	Sitting forward bend(cm)	30 s skipping rope(piece)	Smash(cm)	30 s Crunches(piece)	Standing long jump (com)
10	23.8	80.4	751.4	21.34	117.4
11	24.1	78.2	800.6	21.74	129.1
12	25.2	81.4	795.3	22.21	146.5
13	25.6	91.3	810.5	22.75	149.1
14	24.9	93.3	806.9	23.13	155.3
15	27.1	94.7	808.4	24.21	175.8
16	29.6	95.4	812.1	25.12	178.6

As can be seen from **Table 5**, the comparison results of the special physical fitness indicators of different ages of outstanding female table tennis players show that there are obvious age differences in the three indicators of sitting forward bending, spiking and long jumping. The two indicators of the reentry index and the side-sliding bar, which reflect the level of special speed, basically show a trend of increasing with age.

3.5. Applicability of the device to athletes of different age groups

Table 6 shows the score distribution and variability of athletes with different skill levels and age groups in AI training equipment evaluation.

Table 6. Average scores, standard deviations, and confidence intervals of athletes in different skill levels and age groups.

Athlete Group	Sample Size	Average Score	Standard Deviation	Confidence Interval
Beginner Athletes	30	14.5	1.2	[13.3, 15.7]
Intermediate Athletes	40	16.8	0.9	[15.9, 17.7]
Advanced Athletes	30	18.2	0.7	[17.5, 18.9]
Age Group 10–12	20	15.2	1.4	[13.8, 16.6]
Age Group 13–15	30	16.4	1	[15.4, 17.4]
Age Group 16–18	30	17.6	0.8	[16.8, 18.4]

Table 6 shows the average scores, standard deviations, and confidence intervals of different athlete groups and age groups in a certain test. For the athlete group, the sample size for beginners is 30, with an average score of 14.5, a standard deviation of 1.2, and a confidence interval of [13.3, 15.7], indicating a high degree of variability in beginner scores. The sample size of intermediate athletes is 40, with an average score of 16.8, a standard deviation of 0.9, and a confidence interval of [15.9, 17.7], indicating that their scores are relatively concentrated and their performance is good. The sample size of senior athletes is 30, with an average score of 18.2, a standard deviation of 0.7, and confidence intervals of [17.5, 18.9], indicating stable

performance at higher levels. In terms of age group, the sample size of the 10–12 years old group is 20, with an average score of 15.2, a standard deviation of 1.4, and a confidence interval of [13.8, 16.6]. Its score level is slightly lower and fluctuates greatly. The sample size of the 13–15 age group is 30, with an average score of 16.4, a standard deviation of 1, and a confidence interval of [15.4, 17.4], showing better performance than the lower age group. The sample size of the 16–18 age group is 30, with an average score of 17.6, a standard deviation of 0.8, and a confidence interval of [16.8, 18.4], indicating that in the older age group, the score level and performance are the most stable and excellent. These data indicate that as athletes improve their skills and age, their scoring performance gradually increases and becomes more stable.

4. Conclusions

With the development of artificial intelligence and computer vision technology, sports video analysis has been increasingly favored by researchers. Starting from the application of the "Eagle Eye" system in tennis matches, related researchers and enterprises have also begun to conduct research in other sports video fields. This article takes table tennis competition videos as the research environment, takes table tennis players in videos as the research object, and finally completes a table tennis competition video analysis system based on deep learning. The main tasks are as follows. Based on the athlete data obtained by this system, conduct a comprehensive analysis of table tennis competition videos in terms of detection, tracking, and athlete data. Firstly, the performance of YOLOv4 object detection algorithm is evaluated based on selected test data, including accuracy, IOU value, and mAP accuracy. Through a certain degree of analysis of the algorithm, it has demonstrated good accuracy and precision performance in detection. Although this study has achieved certain results in exploring the physical training effects of table tennis players, there are still limitations. Firstly, the sample size is relatively small and only covers a certain range of athletes, which may not fully reflect the physical condition of all table tennis players. Secondly, testing methods may have certain subjectivity and errors, which can have an impact on the accuracy of the results. Future research should further expand the sample size to cover a wider and more diverse group of athletes, and adopt more objective and accurate testing methods. At the same time, exploring the applicability of this physical training method to other sports, in order to enrich the theoretical and practical system of physical training and provide stronger support for the comprehensive development of athletes.

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