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Designation of Battery Test to Evaluate Aerobic Gymnastic Athlete's Performance

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Abstract

Background and Aim: The performance of China's aerobic gymnasts in international competitions has seen a significant decline over the past decade, following notable successes from 2000 to 2012. In recent years, certain training issues from the past have gradually come to light. Consequently, it holds great significance to delve into the factors and standards influencing the competitive performance of high-level aerobic gymnastic athletes. This study aims to develop a comprehensive battery test to assess and enhance the performance of high-level aerobic gymnasts, addressing existing training inadequacies and competition underperformance.

Materials and Methods: This study was a mix of methods of research and development that followed: (1) reviewing relevant literature on the competitive abilities of aerobic gymnastic athletes, initially selecting influencing factors, and establishing an indicator evaluation system; (2) conducting expert interviews and inviting 9 experts to modify and optimize the indicator system; (3) organizing focus group discussions and inviting 19 experts for consultation to further optimize the indicator system and testing content; and (4) developing testing content, operational procedures, and evaluation criteria for the evaluation indicator system, and conducting correlation tests. Data were primarily analyzed using mean, standard deviation, median, two-class imbalance rate, coefficient of variation, and correlation.

Results: The results found that (1) the factors that affect Chinese aerobic gymnastics athletes' performance include physical performance (physical form, physical function, and physical fitness), skills, and choreography; (2) the battery test, consists of 3 physical form tests, 6 physical function tests, 7 physical fitness tests, 3 skill tests, 3 mental tests, and 6 choreography tests; and (3) after conducting test-retest reliability and organizing the data from both tests, the values ranged from 0.73 to 0.97, which indicated that the data from various tests had high reliability and validity.

Conclusion: A comprehensive battery test assesses these factors, including physical, skills, mental, and choreographic aspects. The test's reliability and validity are high.

Keywords: Athlete's Performance; Battery Test; Aerobic Gymnastic

Introduction

Since the first World Aerobic Gymnastics Championships in 1995, Chinese aerobic gymnasts have participated in the competitions multiple times and achieved excellent results, especially during the period from 2006 to 2012. During this time, Chinese gymnasts were highly competitive, forming a leading group with countries such as Romania, France, and Russia, and occupying an important position in the sport of aerobic gymnastics. However, since 2014, there have been significant changes in the competitive landscape of world aerobic gymnastics, with emerging countries like Japan, South Korea, Mexico, and Vietnam showing strong competitiveness. China's performance in the men's individual, women's individual, and duet events has been relatively poor, and these three events are also relatively weak for Chinese aerobic gymnasts compared to the group events. Compared to gymnasts from countries like Romania and Russia, Chinese athletes indeed have a certain gap in their performance in individual events, which also indirectly proves the phenomenon of underperformance in individual events. Overall, Asian female athletes lag significantly behind elite competitors in terms of explosive power and endurance, which is reflected in the choice of difficult moves and the intensity of choreography. This discrepancy also indicates an insufficiency in athletes' competitive abilities and performances, so comprehensive competitive performance is an essential condition for athletes to achieve excellent results.

Aerobic gymnastics is a highly artistic sport that emphasizes athletes' physical fitness and mental resilience, utilizes technical application as its carrier, and leverages musical accompaniment and artistic arrangement as its means. The improvement of athletes' physical fitness can also promote the improvement

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of sports skill level and overall competitive ability, which is the theoretical basis of our research on the evaluation index system of athletes' physical fitness. Based on the outcomes of aerobic gymnastics competitions, Chinese athletes' performance has shown a relative decline over the past decade. Therefore, this research was designed as a battery test to evaluate an aerobic gymnastic athlete's performance, to enhance athlete performance, and to address competition underperformance. This battery test represents the first tailored evaluation tool focusing on specific performance metrics for aerobic gymnastics in China.

Objectives

To design a battery test to evaluate an aerobic gymnastic athlete's performance

Literature review

1. The development of aerobic gymnastics

Fan (2014) believed that in the context of the 2013-2016 rules, the duration of the overall action was further shortened, the action density was strengthened, and the athletes' exercise intensity to complete the action was higher, so it was necessary to strengthen the anaerobic metabolism of athletes in training.

Wang (2018) focused on the layout of this cycle of aerobic gymnastics by interpreting the content of artistic score evaluation and believed that the evaluation of the content of gymnastics and the main content was more detailed, which put forward specific requirements for the proportion of the two in the overall movement. Although the number of movements evaluated by the difficulty score has decreased slightly, the overall duration of the movement has also been further shortened, which further indicates that there is a clear trend in the constant change of rules, which is that the exercise intensity and load of the overall movement of aerobic gymnastics are increasing, and the ability of anaerobic metabolism is required to be further improved, but the basic endurance level still needs attention. Zhuo (2017) pointed out that aerobic dancers must complete the complete set of aerobic gymnastics movements in the form of dance, and the aerobic pedal stipulated that no difficult or technical movements are allowed in the complete set of movements; the time of the complete set of actions is shortened, and the number of maneuvers is also reduced; the selection range of difficult movements is narrowed, and the number of difficult sets of collective events is reduced.

Through the analysis of the rule changes over the past 20 years, on the one hand, the number of movements evaluated by difficulty scores has declined, which means that the selection of individual action scores requires higher requirements and better physical fitness in athletes. On the other hand, with the shortening of action duration, the overall action structure requirements are further refined, bringing about changes in the energy supply system and metabolic capacity of athletes when they complete the action.

2. *The technical ability of aerobic gymnasts*

Wang Kun et al., (2010) believe that through the biomechanical experimental study of aerobic gymnastics group B horizontal support class action, to determine the completion of the movement of the technology and the characteristics of the main muscle group activity changes, practice group B action should pay attention to the angle control of the shoulder joint, the biceps have an important role in such action, should strengthen the practice.

According to Li (2005), all difficult movements of calisthenics were specifically classified according to the characteristics of movement mechanics, the biomechanical principles and technical characteristics of various movements were analyzed and studied, and the basic laws of the main movement techniques were discussed. Among them, jumping actions should pay attention to body attitude control, reduce rotation radius and inertia, and increase angular speed. In the leg swing action, the first stage should make the body's center of gravity away from the rotation axis, so that the body can obtain enough kinetic energy; The second stage requires the use of the rotational kinetic energy of the body, emphasizing the acceleration and control of the legs, which is the main technical characteristic of completing this type of movement.

Jiang et al (2014) believe that in the take-off stage, the hip and knee joints should be buffered rapidly by bending, and the direction should be controlled. In the air, when the rotation degree is relatively small,

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it is not necessary to reduce the rotation to increase the angular speed. During the landing stage, since the knee joint cannot be bent, the shoulder, elbow, and wrist joints play the main cushioning.

To sum up, at present, scholars mainly analyze athletes' technique application through the method of sports biomechanics but do not give more specific technical improvement plans combined with the theory of sports training. Therefore, how to convert the existing research results into specific suggestions for improving the training quality of athletes remains to be further explored by scholars.

3. Mental toughness of aerobic gymnasts

Zhang (2019) conducted a random investigation of 70 young athletes in the 2018 National Aerobics Championship. By using the Cognitive Trait Anxiety Scale and the Competition State Anxiety Scale, the pre-competition anxiety status of young Chinese aerobics athletes was analyzed from four dimensions, and the causes, influencing factors, and coping strategies of competition anxiety were analyzed. The research shows that the overall anxiety level of young athletes is low, and the level of self-confidence is high, which is conducive to the athletes achieving good results. The internal causes of the competition anxiety of young aerobics athletes are related to the expectation of the competition result, their strength, and the condition of the injury. The external reasons are training and competition factors, coaches and teammates factors, and competitors.

Mansry (2020) mental toughness is a firm, efficient, and flexible mental resource displayed by individuals when implementing and maintaining goal pursuit, which directly affects athletes' sports performance in competition. Through a 24-week experimental control study, it is believed that self-talk and progressive muscle relaxation can help improve the control dimension of athletes' mental toughness. Goal-setting training and representation training help improve the input dimension of athletes' mental toughness. Breathing training and self-confidence training help improve the challenge dimension of athletes' mental toughness. Self-confidence training and goal-setting training can help improve the self-confidence dimension of athletes' mental toughness.

To sum up, scholars have made many achievements in sports psychology and paid more attention to diversified perspectives, which has great reference value for studying the performance of aerobic gymnasts' mental toughness. It also shows that mental toughness is a very important part of the structure of athletes' competitive performance elements, and it is worth our attention to this part of the research.

4. Physical Fitness of Aerobic Gymnasts

Zhao (2021) Aerobics selected outstanding young female athletes in China as the research object, used the Delphi method to select and establish 18 special physical fitness test indexes, and developed evaluation criteria through the tests, believing that athletes with low body fat content performed better, and strength quality was the basis for aerobics athletes to complete movements. Anaerobic endurance is the guarantee for athletes to perform high-intensity movements.

Ge (2021) believes that core strength training helps athletes show good athletic performance. Specifically, good core strength can promote the accuracy of athletes' movements and improve the performance effect of complex movements. At the same time, it also increases the athlete's sense of balance, which can strengthen the stability of the body's center of gravity when the athlete completes the movement, and thus improve the stability of the athlete's overall performance.

Wang Sha (2006), believes in the research that, from the perspective of system theory, the concept of "physical ability" is analyzed, and believes that the composition factors of aerobic gymnasts' competitive ability training content mainly include skills, physical ability, psychology, intelligence, and tactics. Aerobic gymnastics competitive skills training includes basic skills, difficulty skills, and coordination with partners. This is the technical guarantee for athletes to win the game, but also the hard condition of competitive ability. The physical training of aerobic gymnastics includes body form, overall strength, exercise endurance, flexibility, and coordination, which is the physiological basis of becoming a high-level aerobic gymnast, and the supporting conditions of technical use.

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Through synthesizing findings from previous research, the review aims to provide insights into the effectiveness, reliability, and validity of battery tests in evaluating aerobic gymnastic athletes' performance, thereby contributing to the advancement of training and performance assessment in this sports discipline.

Conceptual Framework

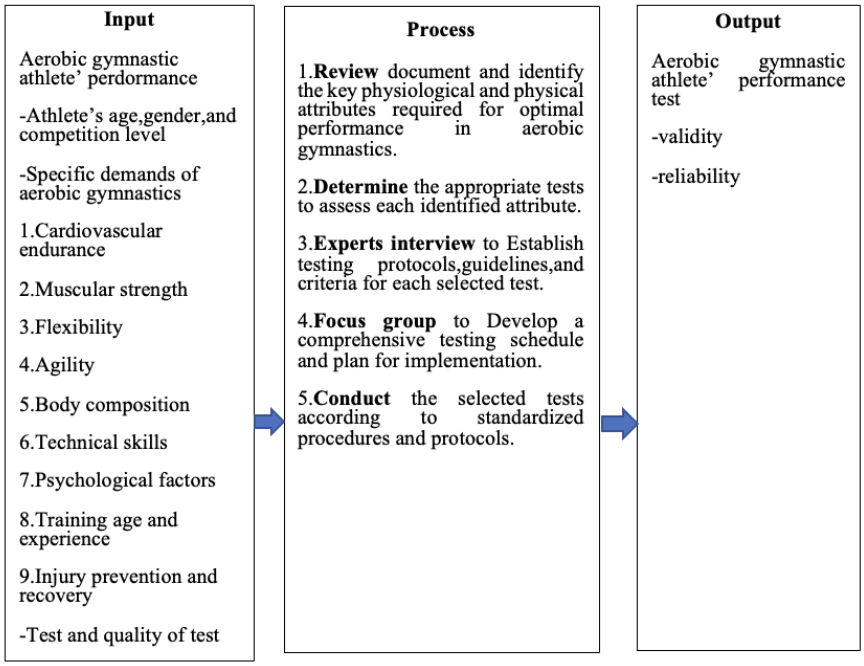

Figure 1 Conceptual Framework

Methodology

1. Population and sample

Since 2017, about 2,000 athletes have participated in the national aerobics competition (the number of participants in lower-level events is not counted). The athletes who participated in the test were selected by the method of purposeful sampling. The scope of selection has been 100 adult athletes since 2017, accounting for 5% of the total, mainly from 10 universities with a high overall level of aerobic gymnastics in China. They include Wuhan Sports University, Chengdu Sport University, Xi'an Sports University, Guangzhou Sport University, Anhui Normal University, Jiangxi Normal University, Shandong Sport University, Shandong Normal University, Beijing Sport University, and East China Normal University.

2. Research Instrument

2.1 Expert Interview Outline

2.2 Questionnaire: There are two types of questionnaires, the first is the "Opinion Form on the Factors Influencing the Performance of Chinese Competitive Aerobic Gymnasts (Expert Questionnaire)" used by experts, evaluated on a Likert five-point scale, and the other is the CSAI scale, which aims to understand the athlete's psychological state.

3. Data Collection

3.1 Expert Interview: The author makes the interview outline and interview table and discusses the influencing factors and specific problems of the aerobics athletes' competitive performance with the experts. Nine experts in the field of aerobic gymnastics participated in the interviews, and the researchers used this information to establish the factors that affect the competitive performance of aerobics athletes.

3.2 Questionnaire: Using the expert questionnaire, feedback was obtained from 19 experts. The experts rated the factors influencing the competitive performance of aerobic gymnasts and the test plan on

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a scale of 1-5. Based on the information and data provided by the experts, the researchers further modified and improved the test plan, ultimately establishing the test for the competitive performance of aerobic gymnasts.

3.3 Scheme Verification: Conduct tests on 30 athletes, compile their test scores, and conduct reliability and correlation tests on the scores obtained from the two tests, to determine the feasibility of the testing protocol.

4. Data analysis

The data with an average and median value greater than 3.5, and an interquartile range (IR) below 1.5, indicate that the experts' opinions are relatively affirmative and tend to be consistent. Data and indicators that do not meet these criteria will be excluded. A correlation value greater than 0.6 in the study indicates a high level of relevance and reliability of the test scheme.

Results

1. To analyze of competition performance factor

Researchers established a testing indicator system for aerobic gymnast competitive performance. According to these indicators, a relevant testing plan for athlete performance was created. This plan was developed based on literature, FIG aerobic gymnastics competition rules, and expert opinions. 9 experts to explore the influencing factors of aerobic gymnastics athletes' competitive performance through open discussions. Experts were asked to rate each indicator and testing plan on a scale of 1-5 using a Likert 5-point scale, where 1-very unimportant, 2-unimportant, 3-neutral, 4-important, and 5-very important. By distributing expert questionnaires and utilizing the Likert five-point scale method, valuable opinions were provided on the removal and addition of various influencing factors, especially suggesting the inclusion of important indicators not mentioned in the draft.

Table 1 Expert opinion (N=9)

Factor	M.dn	CV	IR	Selected
A1.Physical Performance	5	0.10	0.00	Yes
B1.Physical Form	4	0.12	0.00	Yes
C1.Height	4	0.25	0.29	Yes
C2.Weight	4	0.18	0.00	Yes
C3.BMI	4	0.22	0.50	Yes
C4.Proportion of sitting height to overall height	**3***	**0.75**	**2.00**	**No**
C5.Proportion of lower limb length to overall height	**2***	**0.55**	**2.00**	**No**
C6.Proportion of arm length to overall height	**2***	**0.66**	**3.50**	**No**
B2.Physical Function	5	0.12	0.13	Yes
C7.Heart rate	5	0.23	0.00	Yes
C8. Lungs	4	0.17	0.13	Yes
C9. Blood pressure	5	0.12	0.29	Yes
C10.Blood component	5	0.23	0.00	Yes
C11.Lactic acid concentration	4	0.22	0.13	Yes
C12.Basic metabolic rate (BMR)	5	0.12	0.00	Yes
C13.Hormone level	4	0.17	0.00	Yes
B3.Physical Fitness	5	0.08	0.29	Yes
C14.Speed	5	0.19	0.13	Yes
C15.Strength	5	0.17	0.00	Yes
C16.Endurance	5	0.11	0.00	Yes
C17.Flexibility	5	0.16	0.00	Yes
C18.Agility	5	0.11	0.29	Yes

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Factor	M.dn	CV	IR	Selected
C19.Power	5	0.12	0.29	Yes
C20.Aerobic capacity	4	0.22	0.13	Yes
C21.Anaerobic capacity	4	0.12	0.29	Yes
A2.Skill	5	0.08	0.13	Yes
B4.Movement Patterns	5	0.21	0.00	Yes
C22.Step movements	5	0.17	0.00	Yes
C23.Arm movements	5	0.22	0.00	Yes
C24.Trunk movements	4	0.18	0.00	Yes
B5.Special Element	5	0.10	0.00	Yes
C25.Floor class special elements of technology	5	0.12	0.00	Yes
C26.Techniques for emptying special elements	5	0.16	0.00	Yes
C27.Techniques for special elements of the standing class	5	0.10	0.00	Yes
C28.Gymnastics skills class technique	4	0.12	0.00	Yes
C29.Combination of special elements joining class technology	5	0.08	0.00	Yes
B6.General Content	4	0.22	0.13	Yes
C30.Lifting technique	5	0.23	0.00	Yes
C31.Group or peer collaboration techniques	5	0.18	0.13	Yes
C32.Techniques for transition and connection elements	4	0.18	0.00	Yes
A3.Mental	4	0.17	0.00	Yes
B7.Anxiety State and Self-Confidence	4	0.19	0.00	Yes
C33.Cognitive anxiety	4	0.20	0.00	Yes
C34.Somatic anxiety	4	0.22	0.00	Yes
C35.Self-confidence	4	0.19	0.00	Yes
A4.Choreography	5	0.11	0.13	Yes
B8.Aerobic Content	5	0.08	0.00	Yes
C36.The number of elements in the movement pattern	5	0.23	0.00	Yes
C37.The execution quality of the movement pattern	5	0.17	0.00	Yes
C38.Diversity of movement patterns	5	0.17	0.00	Yes
C39.The complexity of movement patterns	5	0.18	0.13	Yes
C40.Exercise mode has sufficient exercise intensity	5	0.12	0.50	Yes
C41.The innovation of movement patterns	5	0.11	0.29	Yes
C42.Motion patterns employ varying pluralism in both planar and 3 - dimensional space	5	0.18	0.80	Yes
C43.Rationality of movement pattern	**3***	**0.35**	**0.25**	**No**
C44.Continuity of movement patterns	5	0.18	0.29	Yes
B9.Special Element	5	0.10	0.00	Yes
C45.The number of special elements	5	0.18	0.00	Yes
C46.Groups of special elements	4	0.17	0.00	Yes
C47.Categories of special elements	4	0.12	0.29	Yes
C48.The execution quality of a particular element	5	0.00	0.00	Yes
C49.The score of a particular element	4	0.13	0.00	Yes
C50.Connection form and bonus points of special elements	5	0.12	0.00	Yes
C51.Special element's root element	5	0.11	0.13	Yes
B10.General Content	5	0.10	0.13	Yes
C52.General content execution quality	5	0.08	0.29	Yes
C53.Complexity of general content	5	0.11	0.00	Yes

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Factor	M.dn	CV	IR	Selected
C54.Fluency of general content	5	0.08	0.13	Yes
C55.Innovation of general content	5	0.12	0.50	Yes
C56.Reasonableness of general content	**3***	**0.36**	**2.00**	**No**
C57.Diversity of general content	5	0.12	0.00	Yes
C58.The use of general content in different spaces	**3***	**0.26**	**2.00**	**No**
B11.The Selection and Application of Music	5	0.12	0.13	Yes
C59.The expression of musical style	5	0.12	0.00	Yes
C60.The appropriateness of the musical theme	4	0.13	0.00	Yes
C61.The rationality of musical structure	4	0.13	0.13	Yes
C62.The appropriateness of rhythm and speed of music	4	0.12	0.29	Yes
C63.The unity of musical style and choreography theme	4	0.12	0.00	Yes
C64.The unity of rhythm speed and movement intensity	5	0.11	0.50	Yes
C65.The quality of the musical material	5	0.12	0.29	Yes
B12.Artistic Arrangement	4	0.18	0.29	Yes
C66.The unity of musical style and choreography theme	5	0.00	0.00	Yes
C67.The program can reflect the distinctive characteristics of aerobic gymnastics	4	0.12	0.00	Yes
C68.Originality and uniqueness of the program	4	0.20	0.29	Yes
B13.Artistic Performance	5	0.11	0.29	Yes
C69.The stage performance of the aerobic gymnastics program	4	0.17	0.50	Yes
C70.Group performances need to reflect the effect of teamwork	5	0.18	0.00	Yes
C71.Play with attraction	4	0.25	0.00	Yes

According to the results, the first-level and second-level indicators were recognized by the experts, with median scores between 4-5, indicating these influencing factors are highly important, with no scores below 3.5. Based on statistical knowledge, this indicates that the experts agree with these indicators and content. The coefficient of variation (CV values) ranged from 0.1 to 0.25, indicating a small degree of dispersion in expert opinions and a trend toward consensus. By counting the number of "yes" and "no" votes from experts, the negative samples were significantly lower than the positive samples, with consistency ratios (IR values) ranging from 0 to 0.8, far below the judgment standard of 1.5. This further demonstrates expert agreement with the first-level and second-level indicators, showing good consensus and recognition.

In the third-level indicators, the points of contention are mainly centered around sub-indicators in physical form, aerobic content choreography, and general content choreography. The indicators for the ratio of sitting height to stature, lower limb length and ratio, and upper limb length and ratio had median scores of 3, 2, and 2, respectively, below the control lower limit of 3.5, with IR values of 2.0, 2.0, and 3.5, above the control upper limit of 1.5. The discussion among experts suggested that an athlete's body morphology is largely determined by innate conditions, with minimal changes resulting from postnatal training. Athletes are typically selected at an early stage of sports recruitment, determining their suitability for certain sports. While limb length and trunk length are factors that influence an athlete's competitive ability, body morphology-related factors cannot directly determine an athlete's competitive performance. Therefore, at this stage, limb and trunk lengths should not be considered as influencing factors in the competitive performance of aerobic gymnastics athletes. Moreover, there are no absolute standards for the lengths of limbs and trunks due to significant variations among individuals, making it difficult to establish uniform assessment criteria. Hence, these indicators will be removed from the questionnaire.

Regarding expert opinions on the choreography part, there was a general disagreement with the rationality of aerobic content, general content, and space utilization as indicators, not recognizing them as

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influencing factors in athletes' competitive performance, with median scores only at 3, below 3.5. This shows a disagreement with these indicators. The IR values for these indicators were also generally high, exceeding the lower control limit of 1.5. These indicators need to be removed. The rationality of choreography should be reflected through an athlete's execution ability, and evaluating whether the arrangement is reasonable through experts is too subjective. Additionally, the general content indicator involves transitional and connecting movements used to link different parts of the program and facilitate spatial transitions, serving their purpose without the need for additional testing to evaluate their application in different spaces.

Based on the above table, we have analyzed and summarized the expert opinions, deleting the unacknowledged content retaining the influencing factors, and test content recognized by the experts.

2. To define performance factor

Based on the aforementioned factors affecting performance, this study devised test contents for evaluating the competitive results of aerobic gymnasts. Subsequently, the researchers developed expert survey questionnaires and topics for group discussions. 19 experts completed the questionnaires based on the prompts, providing feedback and engaging in thematic discussions on the factors influencing the competitive performance of aerobic gymnasts and the establishment of test content.

Table 2 Finally Established Factors Influencing and Test Contents

Finally Established Factors Influencing and Test Contents
A1.Physical Performance
B1.Physical Form
C1.Height
C2.Weight
C3.BMI
C1. Direct Measurement Method Use a stadiometer to measure the vertical distance from the top of an athlete's head to the bottom of their feet. **C2. Direct Measurement Method** Use a body weight scale to measure an individual's weight. **C3. Contact-Type BMI Measurement Method** Use a testing device to calculate the tested individual's Body Mass Index (BMI). The test subject stands on the device with feet parallel, and the device automatically calculates the relevant data of the test subject.
B2. Physical Function
C4. Heart rate
C5. Lungs
C6. Blood pressure
C7. Blood component
C8 .Basic metabolic rate (BMR)
C9. Hormone level
C4. Electronic Measurement Method Utilize a heart rate monitor to measure an athlete's heartbeats per minute while in a resting state. Conduct multiple tests and calculate the average to determine the final result. **C5. Spirometry** Use a spirometer, where the athlete blows continuously into the mouthpiece until the value stabilizes and stops changing on the display, then record the data from the instrument **C6. The method of using a cuff-style sphygmomanometer**

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Finally Established Factors Influencing and Test Contents
Use an electronic sphygmomanometer. While the athlete is at rest, wrap the device around the upper part of the left arm and use the one-click test feature. After the device has finished, record the data displayed on the screen.
C7. CBC(Complete Blood Count)
With the athlete fasting, draw blood and place the sample in a blood analyzer to detect the athlete's data. The main values measured here include red blood cell count, white blood cell count, hemoglobin concentration, and platelet count.
C8. Metabolic Rate Testing Method
The test should be done in the morning, ensuring the athlete has not eaten or exercised for over 8 hours, and is in a fasting and rested state. Using a respirometer, gas analyzer, heart rate monitor, breathing mask, and software, the athlete breathes into the mask. With the mentioned equipment, measure the airflow rate, oxygen, and carbon dioxide concentrations, combine these data, and calculate the results through software.
C9. Saliva Testing Method
For cortisol hormone level testing, ensure the athlete has not eaten, drunk water, or exercised intensely for at least an hour before the test. Collect a saliva sample for ELISA analysis to determine cortisol content. For testosterone level testing, perform a saliva test in the morning. Analyze the obtained saliva sample with laboratory equipment to get the data and results.
B3.Physical Fitness
C10.Speed
C11.Strength
C12.Endurance
C13.Flexibility
C14.Agility
C15.Aerobic capacity
C16.Anaerobic capacity
C10. 30-meter Sprint Test
Instruct the athlete to sprint 30 meters at their maximum speed. The coach uses a stopwatch to record the time it takes for the athlete to sprint from the starting line to the finish line, which is used to assess the athlete's speed ability.
C11. Straddle press handstand Test
Straddle press handstands. The number of repetitions performed by the athlete within one minute is recorded.
C12. 400-Meter Run Test
Instruct the athlete to participate in a 400-meter run test. The coach uses a stopwatch to record the time taken by the athlete to complete the 400-meter run, which is used to evaluate the athlete's endurance level.
C13. Sit and reach test and Splits test
Flexibility testing includes the following 2 items: The Sit and Reach Test is a common flexibility assessment method typically used to measure the flexibility of the lower back and legs. The Front Split

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are method to assess the flexibility of the lower extremities, particularly the legs and hip extension capability. Individuals should undergo these tests without pain and under professional guidance to avoid injury.

C14. T-test

The T-test is utilized to assess an athlete's multidirectional speed and agility. It involves positioning four markers to form a large "T" shape on the ground. The central marker serves as the base of the "T," while the other three markers are placed at the top, with one on each side. The distances between the top three markers and the distance from the central marker to the top center marker are typically set at 10 feet.

C15. VO2 max test (Volume of Oxygen Maximal Test)

The maximal oxygen consumption test (VO2 max) is a very standard method for measuring aerobic capacity. In the test, the athlete gradually increases the exercise intensity on a bicycle ergometer until the point of exhaustion. Throughout the measurement process, the athlete's heart rate, oxygen intake, and carbon dioxide output are recorded. This information can help assess the efficiency of the athlete's cardiovascular system and the muscles' ability to utilize oxygen.

C16. Wingate test

The Wingate test evaluates an athlete's anaerobic metabolism capability by conducting an all-out 30-second cycling sprint on a stationary bike to measure peak power, average power, and total power output. This test provides insights into an individual's anaerobic metabolism capacity.

A2.Skill

B4. Movement Patterns

C17.Step movements

C18.Arm movements

C19.Trunk movements

C17-19. Execution Evaluation

The technical ability testing section adopts a combination of quantitative and qualitative research methods. It is based on FIG competition rules and execution score assessment methods, combined with the practical application of the measurement plan. The testing plan for movement patterns technique includes: Athletes are required to perform a complete routine according to the rules. Four execution score judges are selected to evaluate the athletes, with a maximum of 10 points. The scores given by the 4 judges are averaged after the highest and lowest scores are removed, leaving only the two effective scores. Deduction criteria are divided into 4 levels: Minor mistake -0.1, Moderate mistake -0.3, Major mistake -0.5, and Fall -1.0. The deduction rules come from the FIG competition rules.

B5.Special element

C20.Floor class special elements of technology

C21.Techniques for emptying special elements

C22.Techniques for special elements of the standing class

C23.Gymnastics skills class technique

C24.Combination of special elements joining class technology

C20-24. Execution Evaluation

The technical ability testing section adopts a combination of quantitative and qualitative research methods. It is based on FIG competition rules and execution score assessment methods, combined with the practical application of the measurement plan. The testing plan for the special element technique includes: Athletes are required to perform a complete routine according to the rules. Four execution score judges are selected to evaluate the athletes, with a maximum of 10 points. The scores given by the 4 judges are averaged after the highest and lowest scores are removed, leaving only the two effective

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scores. Deduction criteria are divided into 4 levels: Minor mistake -0.1, Moderate mistake -0.3, Major mistake -0.5, and Fall -1.0. The deduction rules come from the FIG competition rules.
B6.General Content
C25.Lifting technique
C26.Group or peer collaboration techniques
C27.Techniques for transition and connection elements

C25-27. Execution Evaluation

The technical ability testing section adopts a combination of quantitative and qualitative research methods. It is based on FIG competition rules and execution score assessment methods, combined with the practical application of the measurement plan. The testing plan for the special element technique includes: Athletes are required to perform a complete routine according to the rules. Four execution score judges are selected to evaluate the athletes, with a maximum of 10 points. The scores given by the 4 judges are averaged after the highest and lowest scores are removed, leaving only the two effective scores. Deduction criteria are divided into 4 levels: Minor mistake -0.1, Moderate mistake -0.3, Major mistake -0.5, and Fall -1.0. The deduction rules come from the FIG competition rules.

A3.Mental
B7.Anxiety state and self-confidence
C28.Cognitive anxiety
C29.Somatic anxiety
C30.Self-confidence

C28-30. CSAI

This scale divides the psychological assessment of athletes' competitive state into three parts: cognitive anxiety, somatic anxiety, and self-confidence. The distribution and completion of the questionnaire were based on two scenarios: one during the quiet and relaxed state before regular training or practice, and the other before or after important competitions. The questionnaire mainly describes the athletes' psychological activities before or after a competition, with athletes providing answers based on their psychological conditions. Answer choices on the questionnaire include: Not at all, Somewhat, Moderately so, Very much so. After completing the questionnaire, researchers promptly collected and calculated the scores for each questionnaire. Based on the collected data, they then analyzed and concluded the athletes' psychological abilities. The questionnaire reflects three scores: cognitive state anxiety score, somatic state anxiety score, and self-confidence score. Calculation method: Cognitive state anxiety (items 1, 4, 7, 10, 13, 16, 19, 22, 25, calculate the sum of the scores for these questions), somatic state anxiety (items 2, 5, 8, 11, 14, 17, 20, 23, 26, calculate the sum of the scores for these questions), self-confidence (items 3, 6, 9, 12, 15, 18, 21, 24, 27, calculate the sum of the scores for these questions).Scoring criteria: The scores will range from 9 to 36, with 9 indicating low-state anxiety and 36 indicating high-state anxiety.

A4.Choreography
B8.Aerobic Content
C31.The number of elements in the movement pattern
C32.The complexity of movement patterns
C33.Exercise mode has sufficient exercise intensity
C34.The innovation of movement patterns
C35.Motion patterns employ varying pluralism in both planar and 3-dimensional space

C31-35.Artistic Evaluation

The choreography testing section adopts a combined approach of quantitative and qualitative research. It is based on the FIG competition rules and the artistry score assessment method, integrated

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with the development and practical application of the measurement plan. The testing plan for aerobic content is as follows. Athletes perform a complete routine according to the rules. Four artistic judges evaluate the athletes, covering all elements of the routine, with a maximum score of 10 points. The four artistic judges provide an overall artistic score, removing the highest and lowest scores, and considering the average of the remaining two judges' scores as the final score. The artistic judges assess the performance from five aspects, with each aspect having a maximum score of 10 points. This unit focuses solely on the evaluation of Aerobic content, with a maximum score of 10.
B9.Special Element
C36.The number of special elements
C37.Groups of special elements
C38.Categories of special elements
C39.The execution quality of a particular element
C40.The score of a particular element
C41.Connection form and bonus points of special elements
C42.Special element's root element
C36-42.Difficulty and Choreography Evaluation In the choreography test, quantitative research and qualitative research are adopted. According to FIG competition rules and difficulty evaluation methods, combined with the actual development and application of measurement schemes. The test scheme for special element orchestration is as follows: The gymnast performs a complete routine according to the rules. Two difficulty judges evaluate the gymnast's performance, focusing only on the execution of special elements and gymnastic skills. The two difficulty judges give the same score. Calculate the average score. The difficulty judges evaluate the gymnast's performance based on the following aspects: The completion and scoring of special elements. The completion and scoring of special element connections. Whether the composition of special elements meets the requirements of the rules. The maximum score is 10 points, with 4 points for choreography and 6 points for execution. Regarding compliance with the rules in arranging special elements: If the number of special elements meets the rules, 1 point can be obtained; otherwise, 0 points. If the distribution of special elements' groups meets the rule requirements, 1 point can be obtained; otherwise, 0 points. If the distribution of special element categories and root group distribution meets the rule requirements, 1 point can be obtained; otherwise, 0 points. If the form of special element combinations meets the rule requirements, 1 point can be obtained; otherwise, 0 points. Regarding the acknowledgment of the execution of special elements and special element combinations: If all special elements' executions are acknowledged (Credit for Difficulty), 3 points can be obtained. If the execution of special elements incurs a downgrade penalty (Downgrade), 1 point can be obtained. If the execution of special elements incurs a penalty of non-recognition (No Credit), 0 points are obtained. If all special element combinations' executions are acknowledged (Credit vault), 3 points can be obtained; otherwise, 0 points. This section only evaluates special elements. Difficulty score evaluation criteria: The minimum completion criteria for special elements in the FIG competition rules. Special element connection requirements. Composition special regulations. Technical briefings are updated and published annually by the International Gymnastics Federation (FIG) within this cycle.
B10.General Content
C43.General content execution quality
C44.Complexity of general content
C45.Innovation of general content

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C46.Diversity of general content

C43-46. Artistic Evaluation

The choreography testing section adopts a combined approach of quantitative and qualitative research. It is based on the FIG competition rules and the artistry score assessment method, integrated with the development and practical application of the measurement plan. The testing plan for General content is as follows.

Athletes perform a complete routine according to the rules. Four artistic judges evaluate the athletes, covering all elements of the routine, with a maximum score of 10 points. The four artistic judges provide an overall artistic score, removing the highest and lowest scores, and considering the average of the remaining two judges' scores as the final score. The artistic judges assess the performance from five aspects, with each aspect having a maximum score of 10 points. This unit focuses solely on the evaluation of General content, with a maximum score of 10.

B11.The Selection and Application of Music
C47.The expression of musical style
C48.The appropriateness of the musical theme
C49.The unity of musical style and choreography theme
C50.The rationality of musical structure
C51.The quality of the musical material

C47-51. Artistic Evaluation

The choreography testing section adopts a combined approach of quantitative and qualitative research. It is based on the FIG competition rules and the artistry score assessment method, integrated with the development and practical application of the measurement plan. The testing plan for the selection and use of music is as follows.

Athletes perform a complete routine according to the rules. Four artistic judges evaluate the athletes, covering all elements of the routine, with a maximum score of 10 points. The four artistic judges provide an overall artistic score, removing the highest and lowest scores, and considering the average of the remaining two judges' scores as the final score. The artistic judges assess the performance from five aspects, with each aspect having a maximum score of 10 points. This section focuses on the evaluation of the selection and utilization of music, with a maximum score of 10.

B12.Artistic Arrangement
C52.The unity of musical style and choreography theme
C53.The program can reflect the distinctive characteristics of aerobic gymnastics
C54.Originality and uniqueness of the Program

C52-54. Artistic Evaluation

The choreography testing section adopts a combined approach of quantitative and qualitative research. It is based on the FIG competition rules and the artistry score assessment method, integrated with the development and practical application of the measurement plan. The artistic arrangement testing plan is as follows.

Athletes perform a complete routine according to the rules. Four artistic judges evaluate the athletes, covering all elements of the routine, with a maximum score of 10 points. The four artistic judges provide an overall artistic score, removing the highest and lowest scores, and considering the average of the remaining two judges' scores as the final score. The artistic judges assess the performance from five aspects, with each aspect having a maximum score of 10 points. This section focuses on the evaluation of the artistic arrangement, with a maximum score of 10.

B13.Artistic Performance
C55.Group performances need to reflect the effect of teamwork

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C56.Play with attraction

C55-56. Artistic Evaluation

The choreography testing section adopts a combined approach of quantitative and qualitative research. It is based on the FIG competition rules and the artistry score assessment method, integrated with the development and practical application of the measurement plan. The athlete's artistic performance testing plan is as follows.

Athletes perform a complete routine according to the rules. Four artistic judges evaluate the athletes, covering all elements of the routine, with a maximum score of 10 points. The four artistic judges provide an overall artistic score, removing the highest and lowest scores, and considering the average of the remaining two judges' scores as the final score. The artistic judges assess the performance from five aspects with each aspect having a maximum score of 10 points. This section focuses on the evaluation of the athlete's artistic performance, with a maximum score of 10.

Based on the discussions in the focus groups and the feedback from expert surveys, the influencing factors and basic testing contents for the competitive performance of aerobic gymnasts were finally established. Among them, there are 4 first-level indicators, 13 second-level indicators, and 56 third-level indicators.

For the indicators of Physical Form, Physical Function, and Physical Fitness, anthropometric measurement methods were used for testing. In terms of the athlete's skill indicators, the athlete's skill evaluation was conducted using the method of completing the referee evaluation, combining the content of the competition rules and the actual testing situation. For the evaluation of athletes' psychological aspects, the CSAI scale was used to evaluate athletes' anxiety levels and self-confidence. For the choreography section, combining the competition rules and testing practices, the methods of artistic score referee evaluation and difficulty score referee evaluation were used to evaluate the choreographic elements of athletes' competitive performance.

3. To select a test of each performance factor

The research scheme is mainly divided into four parts. The first part focuses on athletic performance, primarily utilizing electronic measuring instruments related to sports training and physiology, as well as daily training equipment. The second part concerns skill testing, which is primarily evaluated through the completion of sub-judges' assessments. This evaluation is mainly based on competition rules, tables, and the basic hardware facilities for aerobic dance teaching and training. The third part involves psychological factor testing, which is addressed through the use of a competitive anxiety level questionnaire. The fourth part concerns choreographic elements, which are primarily evaluated by artistic judges and difficulty judges. Among these elements, the arrangement of special elements is highly specialized, so difficulty judges are selected to evaluate them, while other factors are evaluated by artistic judges. Therefore, the tools involved here include competition rules, tables, and the basic hardware facilities for aerobic dance teaching and training. The specific equipment and measurement units involved in the testing are detailed in the following table.

Table 3 Test Objective, Content

ITEM	OBJECTIVE	CONTENT
Physical form	1. Height	1. Direct Measurement
	2. Weight	2. Direct Measurement
	3. BMI	3. Contact-Type BMI Measurement
Physical function	1. Heart Rate	1. Electronic Measurement
	2. Lung Capacity	2. Spirometry Test
	3. Blood Pressure	3. Cuff-style sphygmomanometer
	4. Blood Composition	4. CBC Test
	5. BMR	5. Metabolic Rate Test

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ITEM	OBJECTIVE	CONTENT
	6. Testosterone and Cortisol	6. Saliva Test
Physical fitness	1. Speed 2. Strength 3. Endurance 4. Flexibility 5. Agility 6. Aerobic Capacity 7. Anaerobic Capacity	1.30-meter Sprint Test 2. Straddle press handstand Test 3.400-Meter Run Test 4.Sit and reach test and Splits test 5. T-test 6.VO2 max test 7. Wingate test
Movement patterns	Step.Hand.Trunk	During the athlete's live performance, the completion score judge evaluates their performance.
Special elements	Aerial special elements, Standing special elements, Floor technique elements.	
General content	Lifting, cooperation, transitions, and connections, gymnastics skills, etc.	
Anxiety level and Self-confidence	Cognitive state anxiety, Somatic state anxiety, and Self-confidence.	Based on the CSAI scale, questionnaire testing is used.
Special elements	Quality, score, group distribution, category distribution, root element distribution of special elements, as well as the connection forms and values of special elements.	Athletes perform on the spot and difficulty judges evaluate based on the content of the competition rules and the actual test.
Aerobic content	Quantity, diversity, complexity, intensity, rationality, continuity of choreography movements, as well as the utilization of diverse spaces, etc.	Athletes perform on the spot, and artistic judges evaluate based on the content of the competition rules and the actual test.
General content	Quality, complexity, fluidity, innovativeness, and diversity.	
The selection and application of music	Expression of music style, appropriateness of theme, rationality of structure, suitability of rhythm and tempo, unity of music rhythm and movement intensity, quality of musical materials, etc.	
Artistic arrangement	Unity of music style and choreography theme reflecting the unique characteristics of aerobic gymnastics, as well as the originality and uniqueness of choreography.	
Artistic performance	The atrical performance effect, partner cooperation effect in team events, and attractive performance.	

4. To confirm the test

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Table 4 Correlation between Two Test Scores

Factor	Test	R
Height	Height Test	0.97
Weight	Weight Test	0.92
BMI	BMI Test	0.90
Heart Rate	Electronic Measurement Test	0.91
Lung Capacity	Spirometry Test	0.84
Blood Pressure	Cuff-style sphygmomanometer Test	0.76
Blood Composition	CBC Test	0.73
BMR	Metabolic Rate Test	0.81
Testosterone	Saliva Test	0.81
Cortisol		0.85
Speed	30 m Sprint Test	0.86
Strength	Straddle press handstand Test	0.80
Endurance	400 m Sprint Test	0.79
Flexibility	Sit and Reach and Front Splits Test	0.88
Agility	T-test	0.89
Aerobic Capacity	VO2 max Test	0.86
Anaerobic Capacity	Wingate Test	0.77
Movement patterns	Evaluation of Execution Score	0.82
Special Element		0.86
General Content		0.79
Cognitive Anxiety	CSAI Scale Test	0.77
Somatic Anxiety		0.78
Self-Confidence		0.76
Special Element	Evaluation of Difficulty Score	0.84
General Content	Evaluation of Artistry Score	0.81
The selection and application of music		0.88
Artistic Arrangement		0.83
Artistic Performance		0.84
Aerobic Content		0.80

After collecting and calculating the relevant data from the first test, a re-test was conducted 7 days later. After organizing the data from both tests, a correlation function test was performed, and the values ranged from 0.73 to 0.97, indicating that the data from various tests were relatively stable and reliable. This suggests that the testing program possesses good reproducibility and stability for test elements, demonstrating high reliability and validity.

Conclusion

The study aimed to develop a comprehensive battery test to assess and enhance the performance of high-level aerobic gymnasts in China, addressing the significant decline in their international performance over the past decade.

The research employed a mixed-methods approach, combining literature review, expert interviews, focus group discussions, and correlation tests. The literature review focused on the competitive abilities of aerobic gymnastic athletes, identifying influencing factors, and establishing an initial indicator evaluation system. Subsequently, expert interviews were conducted with 9 experts to refine and optimize the indicator

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system. This was followed by focus group discussions with 19 experts to further enhance the indicator system and testing content.

The results of the study revealed several key findings. Firstly, the factors influencing Chinese high-level aerobic gymnasts' performance were identified as physical performance (including physical form, physical function, and physical fitness), skills, and choreography. Secondly, a comprehensive battery test was developed, consisting of 3 physical form tests, 6 physical function tests, 7 physical fitness tests, 3 skill tests, 3 mental tests, and 6 choreography tests. Finally, the reliability and validity of the battery test were assessed through test-retest reliability analysis, with correlation values ranging from 0.73 to 0.97, indicating the high reliability and validity of the data obtained from various tests.

Discussion

The study's findings contribute valuable insights into the factors influencing the performance of high-level aerobic gymnasts and the development of a reliable and valid battery test to assess and enhance their performance. The identification of physical performance, skills, and choreography as key determinants aligns with the multifaceted nature of aerobic gymnastics, emphasizing the need for a holistic training approach. Several studies have highlighted the importance of various physical and psychological factors in the performance of gymnasts. For instance, the study on law enforcement recruits demonstrated that upper-body strength and aerobic fitness are crucial for better performance in job-specific tasks, which can be extrapolated to the physical demands of aerobic gymnastics (Lockie, et al, 2018). Similarly, the evaluation of physical and basic gymnastics skills for talent identification in men's artistic gymnastics underscored the significance of muscle strength, flexibility, speed, endurance, and muscle power, which are also critical for aerobic gymnasts (Mkaouer, et al, 2018). Heart rate responses during high-intensity circuit training in female child gymnasts revealed that maintaining a high heart rate for extended periods is essential for improving aerobic fitness, which is a key component of aerobic gymnastics (Salagas, et al, 2020). Additionally, the analysis of factors influencing the artistic performance of competitive aerobics athletes identified special physical quality, psychological quality, and scene atmosphere as significant contributors to expressiveness and overall performance (Tanz & Xu, 2018). The role of aerobic capacity in fatigue development during training sessions for young gymnasts further supports the need for a well-rounded training regimen that includes endurance training to enhance performance and delay fatigue (Sawczyn, et al, 2018). Moreover, the study on the dominant factors of physical ability determining the achievement of artistic gymnastic techniques highlighted the importance of leg muscle strength, which is vital for executing complex aerobic gymnastics routines (Qomarrullah, et al, 2018).

The integration of physical performance, skills, and choreography in training programs is essential for the holistic development of aerobic gymnasts. The findings from various studies emphasize the need for a comprehensive approach that includes strength training, aerobic conditioning, psychological preparation, and skill development to optimize performance in aerobic gymnastics.

The comprehensive battery test, encompassing various dimensions of physical and mental attributes, offers a standardized tool for evaluating athletes' strengths and weaknesses. This approach ensures a thorough assessment of athletes' overall capabilities by including physical form, physical function, physical fitness, skills, mentality, and choreography. About the validity and reliability of testing batteries, the isokinetic, isometric, and functional assessments in return for sports testing batteries demonstrate acceptable validity and reliability, though improvements are needed for muscular endurance assessments (Popchak, et al, 2020). Multimodal assessment batteries, which include balance, cognition, and strength measures, show higher sensitivity and specificity in identifying post-concussion performance deficits compared to individual clinical measures (Toong, et al, 2021). Comprehensive Testing in Specific Sports, developing a comprehensive testing battery for mixed martial arts (MMA) involves assessing aerobic and anaerobic function, strength, body composition, and repeat effort ability. This approach is feasible and provides valuable insights into the physiological profiles of athletes (Plush, et al, 2021). Motor Competence in Talent Identification, The KTK (Körperkoordinationstest für Kinder) is effective in distinguishing

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between athletes of different competition levels and sporting domains, it is a useful tool in the talent pathway for assessing motor competence, unaffected by maturation, gender, or playing positions (O'Brien-Smith, et al, 2019). Therefore, the comprehensive battery test is a valuable tool for evaluating athletes' overall capabilities, it ensures a thorough assessment by including various dimensions of physical and mental attributes, and the validity and reliability of such testing batteries are well-supported, particularly when using multimodal approaches. Specific sports, like MMA, benefit from tailored comprehensive testing batteries, while tools like the KTK are effective in talent identification across different sports.

Recommendation

1. Significance for Coaches' Training Decision-Making

The results of this study indicate that a comprehensive and multi-dimensional evaluation is required for the competitive performance of calisthenics athletes. Therefore, teachers and coaches should avoid making hasty judgments based solely on experience when analyzing athletes' competitive abilities and conducting training diagnoses. Instead, they should objectively evaluate the athletes' current training status through scientific testing programs and propose targeted training improvement strategies and methods based on the athletes' shortcomings in competitive abilities, thereby effectively enhancing their competitive abilities.

2. Establishing Quantitative Evaluation Criteria

Through the development of the testing program in this study, evaluation methods and criteria have been proposed. Previous studies mostly focused on summarizing the results of sample tests and did not specifically propose testing programs and evaluation criteria. Based on this research, the researcher has provided methods and evaluation criteria for the competitive performance testing of calisthenics athletes, further quantifying the evaluation of their competitive abilities.

3. Recommendations for Further Research

The testing methods need to be upgraded. With technological advancements and economic development, there is potential for further upgrading of future testing methods and content, and we can carefully consider the addition of new methods and means in the future.

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