Image Processing Techniques for Evaluating and Modeling Athletes' Cognitive Abilities and Sports Performance

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Abstract
To delve into the relationship between athletes' cognitive abilities and sports performance, this article adopted image processing analysis and modeling techniques. By analyzing athletes' behavior during competitions, it was found that athletes' cognitive abilities had a significant impact on their sports performance. A professional camera equipment with high resolution, high frame rate, and low noise was chosen to capture moving images from multiple positions and angles. Pre-processing was performed on the collected images. Wavelet analysis method was used for denoising. Residual encoding and decoding network were used for image correction, and grayscale co-occurrence matrix method was used for image feature extraction. In terms of sports accuracy, the distribution of sports accuracy among the 10 athletes in the high-level sports cognitive level group was between 98.02% and 99.99%: in terms of overall reaction errors, the higher the overall reaction error index, the better the exercise performance. The comprehensive response error index of the high-level sports cognition group during 10 basketball training sessions ranged from 3.29 to 3.82, with each index higher than the other two groups; in terms of operation thinking time, the shooting positioning operation time of the high-level sports cognition group was particularly short, and the low-level sports cognition group was on the contrary. The experimental results indicated a significant relationship between cognitive ability and motor performance. High-level athletes performed better in cognitive abilities and their athletic performance was also better.
Keywords: Athletes' Cognitive Abilities and Sports Performance, Image Processing Techniques, Questionnaire Testing Method, Wavelet Analysis, Gray Level Co-occurrence Ma-Trix.

Introduction

Technology in sports science has become advanced through the use of various applications to help in evaluating the performances of athletes and improving them. One of the most hopeful technologies available is image processing, which is a form of analysis using Computational techniques to process visual information. In this regard, it can be concluded that this technology can be harmful in assessing the prospective performance of the athletes and the general assessments of their cognitive functional capabilities and performance in sports. Suinn (1997) associate perception, attention, memory, and decision-making functions in cognition with sports. Interactive understanding directly leads to the ability of the athletes to process information as fast and as efficiently as possible and it has the potential to define the final results of a certain contest (Suinn, 1997). Some common methods used to determine the effects of sports on mental health of athletes involve parameters that largely depend on subjective judgment or computer-controlled environments that cannot mirror the real conditions. Conversely, using image processing is more practical, accurate and active than using these tests to assess these abilities as it will reflect and give a clear picture of how the athlete is during actual sports activities. A final consideration is that there is a matrix of interdependence between cognitive abilities and physical fitness. The boost in the mental processes could lead to enhanced decision-making capability grounded on integrated strategy, faster response times, and increased level of performance. On the other hand, physical tasks achieve completion through muscular work and as such mental demands of sports can affect physical work in a way that both enhance and inhibit each other contributing to the understanding of training and performance. In this study, the research questions are as follows: This research seeks to establish the viability of applying image processing in assessment of cognitive competence and athletic performance in athletes. This can help in creating increased awareness and viewing of the student through the ability to see and assess each of the categories as indicated in the video footage and other forms of data that deal with the student's performance. The

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application of image processing technology in training could go a long way in improving training programs, better ways of preventing injuries, and enhancing the understanding of what may be behind an athlete's high-level performance.

The rest of the study is organized: section 2 provides an overview of literature review, section 3 describes measurement and evaluation of Athletes' cognitive ability, section 4 is about image processing evaluation of motion performance, section 5 is discussion on experimental verification and evaluation and section 6 concludes the study.

Literature review

The cognitive ability and performance of athletes are important research directions in the field of sports, and image processing technology provides powerful tools for analyzing and modeling sports processes. This article aimed to study the relationship between athletes' cognitive ability and sports performance and used image processing technology for analysis and modeling to gain a deeper understanding of the impact of athletes' cognitive ability on sports performance.

Investigation on the Relationship between Athletes' Cognitive Ability and Sports Performance

The cognitive ability and performance of athletes are important research directions in the field of sports. Hu Bin believed that people in the whole process of participating in sports included cognitive activities. Sports performance was the specific form of sports cognitive ability, which played an important role in further improving students' sports learning ability and was an important basis for guiding themselves and others to carry out physical exercise. Therefore, in the process of physical education teaching, physical education teachers should flexibly apply knowledge related to the cognitive principles of sports and impart it to students, guide them to carry out practical exercises reasonably, and organically combine physical and mental exercises. They should continuously improve their tactical application level, thus better carrying out sports exhibitions and competitions. There was currently a large amount of research on the impact of music on athletes' physical performance, but there was little information on how music affected athletes' cognitive performance (Hu, 2019). Jarraya and Jarraya (2019) chose to conduct RT (Reaction Time) tests, obstruction tests, tracking tests, and origami tests in the absence of music or immediately after 10 minutes of listening to music to evaluate the impact of listening to music and listening time on the cognitive abilities of Tunisian tennis players. At the beginning of each training session, oral temperature was measured. It was found that listening to music could improve cognitive ability, which in turn had a positive impact on motor response (Jarraya & Jarraya, 2019). Davis L's research aimed to investigate the correlation between the quality of coach athlete relationships and athlete fatigue by assessing physiological and cognitive consequences. He measured the physical performance of athletes in the 5-meter round trip test, and then conducted a Stroop test to evaluate cognitive performance. The structural formula model revealed a positive correlation between the quality of coach-athlete relationships and Stroop performance, as well as a negative correlation between the quality of coach-athlete relationships and cortisol responses to high-intensity exercise, cognitive testing, and fatigue (Davis et al., 2018). Scharfen and Memmert (2019) believed that the combination of extraordinary physiological abilities with excellent motor control, perception, and cognitive functions was the key to achieving excellent results in sports. By summarizing and comparing previous studies, the differences in cognitive function that might exist due to age, skill level, and cognitive tasks used were analyzed, and it was found that experts and elite athletes had superior cognitive function (Scharfen & Memmert, 2019). Future research should further explore the relationship between athletes' cognitive ability and sports performance and consider the comprehensive influence of other factors to promote the development of sports and improve athletes' competitive level.

Application of Image Processing Technology in the Field of Sports

The application of image processing technology in the field of sports is a highly concerned research field. With the continuous development of image processing technology and the gradual recognition of the relationship between athletes' cognitive ability and sports performance, more and more researchers are exploring the application of image processing technology in the field of sports. Image processing technology can be used to analyze athletes' motor skills and performance. By capturing the subtle movements and techniques of athletes through inter frame differences and motion detection in competition videos, and studying their sports strategies and technical essentials, these analysis results can provide guidance for coaches and help athletes improve their technical level and competitive performance (Wang, 2022). Yuan et al. (2022) elaborated on the specific applications and advantages of image processing technology in fields such as sports performance prediction, competition rule formulation, and referee assistance decision-making. He believed that image processing technology provided scientific guarantee for athletes, including but not limited to improving tactical ability, achieving fair judgment, obtaining big data and building champion models. At the same time, a new mode combining motion technology and image processing technology based on deep learning theory was proposed (Yuan et al., 2022). Liu (2022) used image processing technology to real-time recognize and detect human posture during sports training, and proposed an image acquisition method that combined feature extraction based human posture image recognition with frame segment scanning; he also used the fused edge contour Eigen decomposition of a matrix method to deeply process the visual feature expression of human posture, built the fusion degree analysis model of human posture image, and realized the image DE blurring degree processing (Liu, 2022).

Summary

In summary, the application of image processing technology in the field of sports has broad prospects and important research value. Therefore, this article used image processing technology to comprehensively and accurately analyze and model the relationship between athletes' cognitive ability and sports performance, providing scientific guidance and support for athletes' training and competition. Taking athletes in R city as an example, this article first measured and analyzed their cognitive abilities, and then collected images of sports performance for processing and analysis. Finally, based on the extracted sports performance characteristics and athletes' cognitive ability data, a relational model was established to study the impact of athletes' cognitive ability on sports performance. In the experimental section, four aspects were selected for verification: sports success rate, sports accuracy, comprehensive reaction errors, and operational thinking time.

Measurement and Evaluation of Athletes' Cognitive Ability

Formulas and Image Processing Techniques for Comprehensive Assessment of Athletic Performance

To support the evaluation and modeling of athletes' cognitive abilities and sports performance using image processing, several formulas and mathematical models are typically employed. These formulas help quantify various aspects of performance and cognitive function. Below are some relevant formulas and concepts that could be utilized:

To analyze the motion of athletes, kinematic equations and image processing techniques are used to calculate velocity (v), acceleration (a), and displacement (d). Velocity is defined as

$$v = \frac{d}{t}, \quad (1)$$

where t is the time taken. Acceleration (a) of athletes can be calculated using

$$a = \frac{\Delta v}{\Delta t}, \quad (2)$$

where Δv is the change in velocity and Δt is the change in time. The reaction time is another important factor. Reaction time (RT) can be measured using video analysis to determine the time interval between a stimulus and the athlete's response.

$$RT = t_{response} - t_{stimulus}, \quad (3)$$

where $t_{response}$ is the time when the athlete begins to respond and $t_{stimulus}$ is the time when the stimulus is presented.

Cognitive load refers to the amount of mental effort being used in the working memory. It plays a crucial role in athletes' performance, as high cognitive load can negatively impact their ability to make quick and accurate decisions. Understanding and measuring cognitive load can help in designing better training programs and strategies to optimize performance. Cognitive load can be estimated using metrics like fixation duration (FD) and saccades from eye-tracking data.

$$FD = \frac{\sum_{i=1}^{n} f_i}{n}, \quad (4)$$

where f_i is the duration of the i^{th} fixation and n is the total number of fixations.

The Performance Index (PI) is a composite score that integrates various performance metrics to provide a single, comprehensive measure of an athlete's performance. It helps in assessing and comparing the overall performance by combining different aspects such as physical, technical, and cognitive abilities. Here are steps and examples to formulate a Performance Index for athletes using image processing data. Performance indices can be created to combine multiple performance metrics into a single score.

$$PI = w_1 \cdot M_1 + w_2 \cdot M_2 + \cdots + w_n \cdot M_n, \quad (5)$$

where M_i are different performance metrics and w_i are their respective weights

Error rate (ER) in performance can be evaluated by counting the number of errors made in a specific task.

$$ER = \frac{E}{T} \times 100 \quad , \quad (6)$$

where E is the number of errors and T is the total number of attempts.

To assess decision-making accuracy, Signal Detection Theory (SDT) can be applied. The key metrics are the hit rate and false alarm rate.

$$\text{d-prime } (d') = Z(H) - Z(F), \quad (7)$$

where Z is the z-score, H is the hit rate, and F is the false alarm rate.

Common image processing metrics include Mean Squared Error (MSE) and Structural Similarity Index (SSIM) for evaluating image quality.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(I_i - K_i)^2, \quad (8)$$

where I_i is the value of the original pixel, K_i is the value of the compressed/reconstructed pixel, and N is the number of pixels.

These formulas and concepts form the basis for quantitatively evaluating and modeling athletes' cognitive abilities and sports performance using image processing techniques.

Definition and Classification of Athlete Cognitive Ability

Athlete's cognitive ability refers to the individual's ability to perceive, process and judge sports related information when performing sports. It is one of the important influencing factors of sports performance. Athlete's cognitive ability refers to the ability of athletes to perceive, analyze, make decisions and control attention on sports related information in the process of sports (Li, Li, & Chen, 2023; Yu, Yu, & Xu, 2019). Athlete cognitive ability is an important component of sports performance, which directly affects the level and performance of athletes in competitions.

Athletes' cognitive abilities are mainly divided into three categories: perception, decision-making, and attention, as shown in Figure 1.

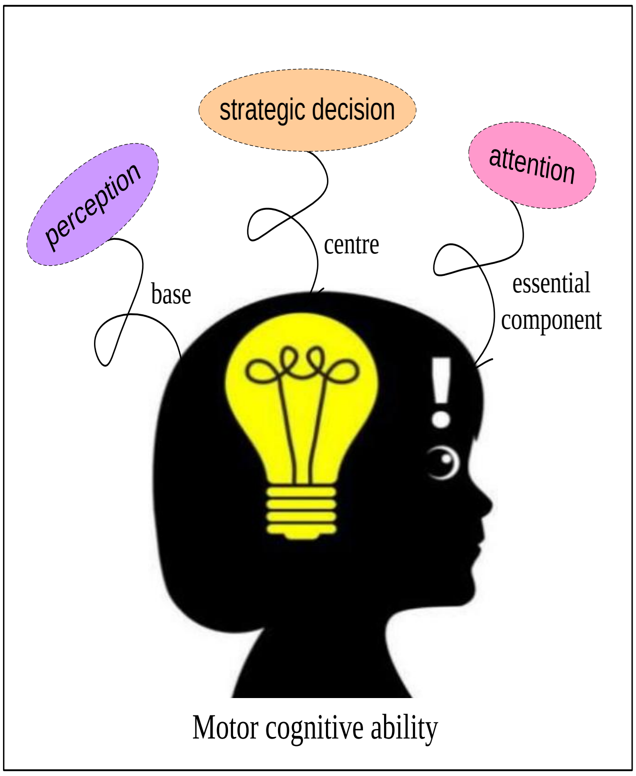

Figure 1: Classification Framework of Motor Cognitive Ability.

Perception is the foundation of an athlete's cognitive ability, which refers to their ability to perceive and obtain information from the external environment. Athletes can timely and accurately obtain information about the playing field, opponent's position, ball speed, and other factors through their perceptual abilities, thus making corresponding reactions and decisions.

Decision making is the core of an athlete's cognitive ability, which refers to their ability to think and make choices based on perceived information when facing complex competition situations. The decision-making ability of athletes directly determines their performance and results in competitions. Excellent decision-making ability can enable athletes to make correct decisions at critical moments and improve their chances of winning the competition.

Attention is an important component of an athlete's cognitive ability. Good attention can help athletes grasp the critical moments of competition, and accurately judge the opponent's actions and intentions, thus making better reactions and decisions. The allocation and control of attention have a significant impact on the performance and performance of athletes.

In summary, athletes' cognitive abilities mainly include abilities in perception, decision-making, and attention. They interact and influence each other, and together determine the performance and results of athletes in competitions. Therefore, the research and analysis of athletes' cognitive ability is of great significance for improving their training effectiveness and competitive level. In the following research, image processing technology would be used to deeply explore and model athletes' cognitive ability and sports performance, with the aim of contributing to the development of the sports field.

Measurement Tools and Methods

The relationship between athletes' cognitive ability and sports performance has always been a research hotspot in the field of sports. In order to better analyze and model this relationship, research requires appropriate measurement tools and methods. This article would introduce commonly used tools and methods for measuring athletes' cognitive abilities, including questionnaire surveys, cognitive tests, and biological measurements.

A questionnaire survey is a common measurement tool that asks athletes a series of questions to understand their cognitive abilities. Questionnaire surveys can cover a wide range of topics. By analyzing the results of the survey questionnaire, the performance of athletes in different cognitive abilities was understood, and the relationship between these abilities and sports performance was studied.

Cognitive testing is another commonly used measurement method that evaluates athletes' cognitive abilities through specific test items. The cognitive test items selected in this paper included reaction time test, attention test, spatial orientation achievement test. Through these tests, athletes' levels of different cognitive abilities are objectively evaluated and correlated with their sports performance.

In addition to questionnaire surveys and cognitive tests, biometrics are also an important measurement method. Biometrics can assess the cognitive ability level of athletes by detecting their physiological indicators. For example, by measuring physiological indicators such as heart rate, blood pressure, and eye movement, athletes' cognitive abilities such as attention and reaction speed during exercise are understood.

In summary, questionnaire surveys, cognitive tests, and biometrics are commonly used tools and methods for measuring athletes' cognitive abilities. Through these tools and methods, the cognitive ability level of athletes can be comprehensively and objectively evaluated, and the relationship between cognitive ability and sports performance can be deeply studied.

Data Collection and Processing

Data collection and processing are crucial links in image processing analysis and modeling research of athletes' cognitive ability and sports performance. This article provided a detailed introduction to the process of data collection, including experimental design, selection of data collection equipment, and data processing methods.

Before conducting data collection, a reasonable experiment was designed. The experimental design should take into account factors related to athletes' cognitive ability and sports performance and follow scientific research principles. Taking athletes from R city as an example, four different age groups of athletes were selected for a sport's cognitive ability questionnaire survey. The four different age groups were as follows: 14-18 years old, 19-23 years old, 24-28 years old, and 29-33 years old. 24 individuals were selected from each age group, including 12 male athletes and 12 female athletes, totaling 96 individuals. As shown in Figure 2, participants were required to complete the questionnaire within the specified time frame, with a total of 20 questions divided into 0, 1, 2, 3, and 4. 0=no; 1=occasionally; 2=sometimes; 3=often; 4=always. Participants should make choices based on their feelings from the past month, including today. The respective total scores were calculated. A questionnaire score between 28 and 30 was considered particularly good for motor cognitive ability. A score below 28 was considered average in motor cognitive ability. A score of over 30 was considered poor in motor cognitive ability.

Athlete Cognitive Ability Test Questionnaire

This questionnaire consists of 20 questions categorised as 0,1,2,3,4. 0=No, 1=Occasionally, 2=Sometimes, 3=Often, 4=Always. Please make your choice based on how you have felt in the last month, including today. Then calculate your score for each item to add up to give you a total score.

1.I want to look confident in front of my opponents

2.I would like psychological support from the coaches

3.Injured a lot in the game, would think it was because of bad luck

4.If you train longer than others, you should get good grades.

5.Athletes must be committed to winning

6.Want to be judged favourably by others on their performance in the game

7.I'm worried that people will look down on me if I don't do well in the competition.

8.People judge me based on my race results.

9.It doesn't feel good to play in an unfamiliar venue.

10.I'm always trying to figure out the details of every move before a game.

11.The crowd is watching me play. I don't feel comfortable.

12.Trying to stay calm when the game isn't going well.

13.I've got my strength back and I'm sure I'll do well.

14.Confident in their motor skills

15.I can easily change my motor skills

Parse

Scores between 28 and 30 are classified as exceptionally good motor cognitive skills, scores below 28 are classified as average motor cognitive skills, and scores above 30 are classified as poor motor cognitive skills.

Figure 2: Athlete Cognitive Ability Questionnaire Test.

The questionnaire test results are shown in Table 1.

Table 1

Results of Sports Cognitive Ability Questionnaire Test (Unit: Person)

Age	Talented		General		Poor	
	Man	Woman	Man	Woman	Man	Woman
14-18	7	5	4	4	1	3
19-23	8	9	2	2	2	1
24-28	11	10	1	1	0	1
29-33	12	12	0	0	0	0

The selection of data collection equipment is also very important. This is because devices can help collect data on athletes' cognitive abilities. When selecting equipment, it is necessary to consider the accuracy, sensitivity, and reliability of the equipment to ensure the quality and credibility of the data. Therefore, this article chose motion cognitive sensors to collect data. This device can collect data by measuring athletes' brain waves, eye movements, muscle signals, and other aspects, helping coaches and researchers better understand athletes' cognitive abilities and provide them with better training and competition strategies.

After the data collection is completed, image filtering, feature extraction, and image segmentation are used for data processing. Through these processing methods, features related to athletes' cognitive ability and sports performance are extracted, and further analysis and modeling are conducted.

In summary, data collection and processing are an indispensable part of image processing analysis and modeling research on athletes' cognitive ability and sports performance. Through scientific experimental design, appropriate data collection equipment selection, and effective data processing methods, accurate and reliable data can be obtained, laying a solid foundation for subsequent analysis and modeling work.

Image Processing Evaluation of Motion Performance

Motion Image Data Acquisition and Preprocessing

Sports image data collection is one of the important means to study the process of athletes' sports (Wang et al., 2018). In the collection of sports image data, it is necessary to use professional sports camera equipment to record and capture the athlete's movement process. Generally speaking, the collection device should have characteristics such as high resolution, high frame rate, and low noise to ensure that the collected image data is high quality and accuracy.

In the process of collecting motion image data, it is also necessary to consider the relative position and angle between the athlete and the camera. The selection of distance and angle between athletes and cameras would directly affect the quality of collected image data and the integrity of information. In order to obtain more comprehensive and accurate image data, multi angle and multi position camera arrangements can be used to comprehensively record and capture the movement process of athletes.

For the entire process of collecting motion image data on the front of athletes, a planar fixed point fixed focus scanning is selected, and the scanning method is from far to near and from near too far. The camera follows the athlete's footsteps closely.

Image preprocessing is an important step in processing and optimizing the collected motion image data. Firstly, image denoising is one of the fundamental tasks of image preprocessing. Due to the potential interference of environmental noise on moving image data, the wavelet analysis method in image processing technology is used to denoise the image data to improve its clarity and accuracy (Xu et al., 2022; Zhang & Cao, 2023), as shown in Figure 3.

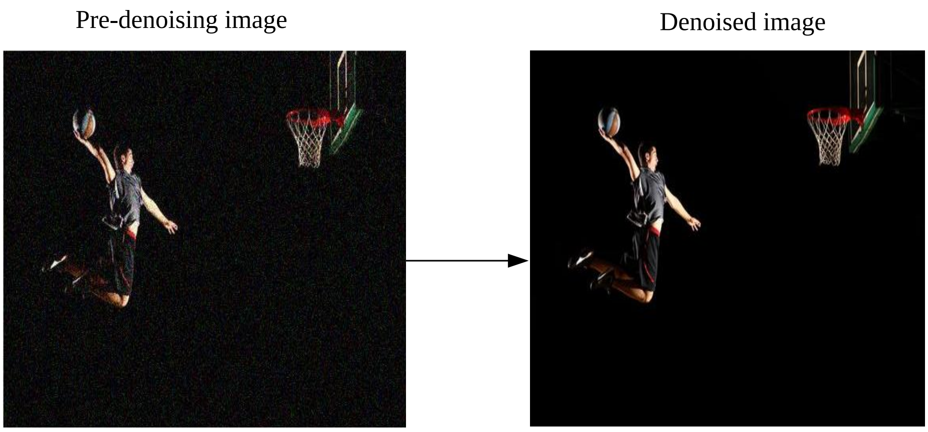

Figure 3: The Denoising Effect of Moving Images.

A moving image is generally regarded as a two-dimensional signal, which is F (x, y). The wavelet transform algorithm is utilized. Scale function and wavelet function are used to transform motion behavior images. The formulas obtained are as follows:

$$W_F(a,b,c,d) = \iint_{-\infty}^{\infty} F(x,y)\ \psi^*\left(\frac{x-b}{a},\frac{y-d}{c}\right) dx\, dy, \quad (9)$$

Where $\psi(x,y)$ is the mother wavelet function, a and c are the scaling parameters along the x and y axes, respectively, b and d are the translation parameters along the x and y axes, respectively. While ψ^* denotes the complex conjugate of the wavelet function.

In practice, the discrete wavelet transform (DWT) is often used for computational efficiency. The DWT can be expressed as:

$$W_{j,k}(m,n) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(x,y)\,\psi_{j,k}(x-m, y-n), \quad (10)$$

where (m,n) are discrete translation parameters, and $\psi_{j,k}$ are the discrete wavelet functions.

The large wavelet coefficients mainly contain useful motion image data, while the small wavelet coefficients have concentrated noise energy. The wavelet coefficients corresponding to the noise are eliminated through threshold, which can effectively suppress the noise in the motion image and also improve the signal-to-noise ratio of the motion image. The threshold definition formula is as follows:

$$W_{j,k}(m,n) = \begin{cases} W_{j,k}(m,n)\ if\ |W_{j,k}(m,n)| \geq T \\ 0\ if\ |W_{j,k}(m,n)| < T \end{cases}, \quad (11)$$

The moving image needs to be corrected to present the true shape and proportion of the moving objects in the image, improving the reliability and availability of image data. For the collected distorted motion graphics, corner detection is used in image processing technology, and the original image corners are extracted. Based on this, an image correction algorithm using residual encoding and decoding network is used. As a connection form of residual encoding and decoding networks, skip structures have the potential to improve network performance degradation and gradient vanishing issues (Chen, 2023; Mou, Lu, & Zhou, 2020). During the encoding process of the residual network, a decoding framework for the residual encoding and decoding network is designed by removing the connection layer and pooling layer to complete the correction of distorted images, as shown in Figure 4.

Figure 4: Comparison Before and After Image Correction.

The preprocessing of collected motion performance images not only includes image denoising and image correction, but also requires image enhancement to make the images easier to analyze and process, as shown in Figure 5.

Histogram equalization is an image enhancement technology used to enhance image contrast and brightness. The basic idea is to redistribute the pixel value distribution of an image, so that the grayscale of the image is evenly distributed throughout the entire range. This can be achieved by transforming the grayscale histogram of the image.

Figure 5: Comparison of motion Image before and after enhancement.

In summary, the collection and preprocessing of sports image data is a key link in studying athletes' cognitive ability and sports performance. Through scientific and reasonable image acquisition methods and image preprocessing steps, high-quality motion image data can be obtained, and valuable feature information can be extracted from it, thus providing strong support for further research and analysis.

Extraction and Evaluation of Motion Performance Features

Action posture is one of the most intuitive features in motion images. Through digital image processing in image processing technology, the human posture in moving images is automatically recognized and extracted, as shown in Figure 6.

Figure 6: Automatic Recognition and Extraction of Human Posture in Motion Images.

The collected motion images have different texture features, which can be extracted using the texture feature extraction method in image processing technology: grayscale co-occurrence matrix method, as shown in Figure 7. Gray Level Co-occurrence Ma-trix (GLCM) is an image texture analysis method that can reflect the spatial information of different pixel relative positions (Huang et al., 2023; Zhang et al., 2023).

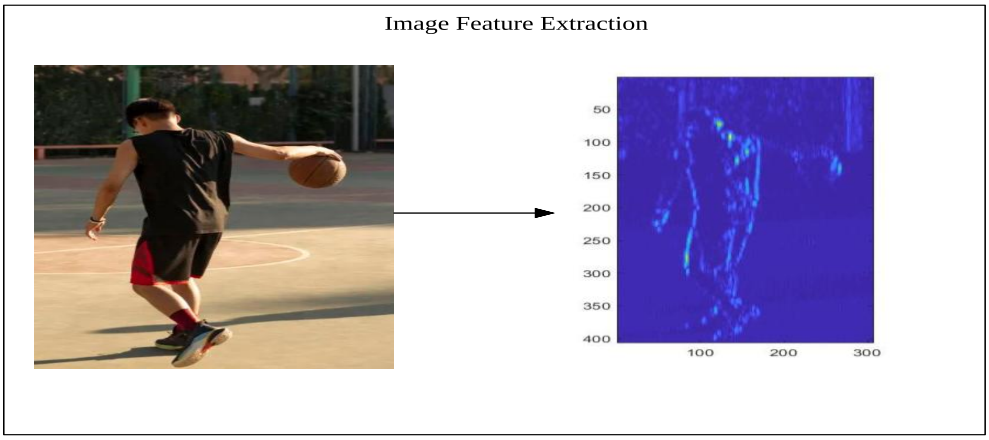

Figure 7: Feature Extraction of Moving Images Using Grayscale Co-Occurrence Matrix.

The formula for calculating the probability of pixels with grayscale o and p appearing in a moving image is as follows:

$$P(p \mid o) = \frac{P(I(x,y,t)= o, I(x,y,t + \Delta t)= p)}{P(I(x,y,t) = o)}, \quad (12)$$

where $P(I(x, y, t) = o)$ is the marginal probability of the pixel having grayscale value o at time t.

Three grayscale co-occurrence matrix features in motion images are extracted for classification of motion behavior. Specifically, it is as follows:

$$Energy = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} P(i,j)^2, \quad (13)$$

Second order moment (ASM): This refers to the measure of image uniformity. The more uniform the gray distribution of an image is, the larger its corresponding second order moment would be. On the contrary, the smaller its second order moment would be.

$$Contrast = \sum_{n=0}^{N-1} n^2 \left(\sum_{i=0}^{N-1} \sum_{j=0}^{N-1} P(i,j) \mid i - j \mid = n \right), \quad (14)$$

Contrast (CON): This refers to the degree of grayscale change in the local image. The greater the difference in grayscale values in the image, the sharper the edges of the image, and the greater the contrast.

Image feature extraction is an important part of motion image data preprocessing. By using appropriate image feature extraction methods, feature information related to athlete posture, movement, speed, etc., can be extracted from motion image data, providing strong support for subsequent motion performance analysis and modeling.

Experimental Verification and Evaluation

Modeling the Relationship between Athlete Cognitive Ability and Sports Performance

Based on the movement performance characteristics and athlete cognitive ability data extracted by image processing technology, a relational model is established, as shown in Figure 8. Sports cognition is the key to perceiving and distinguishing information on the sports field. Attention, reaction speed, judgment, decision-making and execution abilities, and sports performance are performance data in actual competitions or training, such as sports accuracy, operational thinking time, comprehensive reaction errors, competition victory rate, speed, and other information.

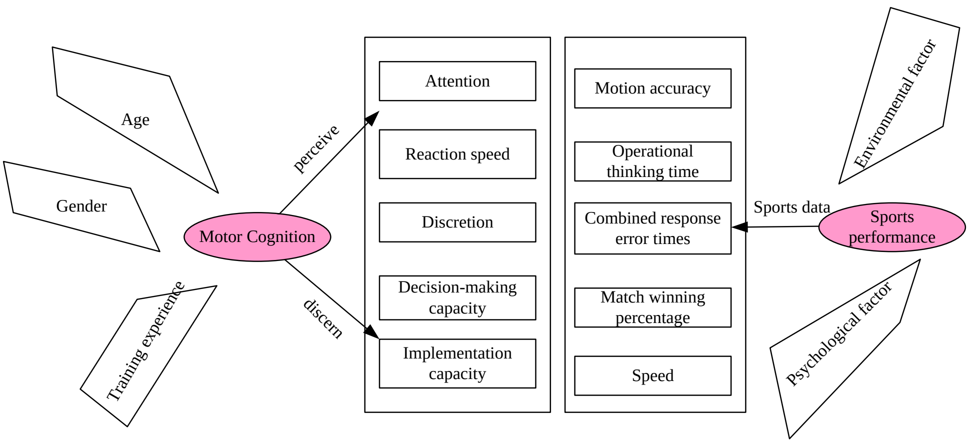

Figure 8: Modeling of the Relationship Between Athlete Cognitive Ability and Sports Performance.

The modeling of the relationship between athletes' cognitive ability and sports performance also requires consideration of relevant factors and mechanisms. For example, the cognitive ability of athletes may be influenced by factors such as individual age, gender, and training experience. In addition, exercise performance may also be influenced by environmental factors, psychological factors, etc. Therefore, when building a relational model, it is necessary to comprehensively consider these factors and explore the interaction and influence between them.

Experimental Design and Participant Recruitment

The experimental design of image processing analysis and modeling research on athletes' cognitive ability and sports performance is as follows:

1) Experimental purpose: The aim is to explore the relationship between athletes' cognitive ability and sports performance, and to model athletes' sports performance through image processing and analysis techniques.
2) Experimental subjects: 200 basketball players with a certain sports foundation were selected from R city as the experimental subjects. Questionnaire tests and cognitive tests were used, with a total of 3 test results. 10 athletes were randomly selected from each result and divided into 3 groups: low-level sports cognition group, medium-level sports cognition group, and high-level sports cognition group. For the convenience of experimental operation, the low-level motor cognition group was set as T1; the medium-level motor cognition group was set as T2; the high-level motor cognition group was set as T3.
3) Experimental process: Firstly, the cognitive ability tests of athletes before the experiment are recorded, including memory, attention, decision-making ability, and execution ability. Athletes' performance tests are recorded, and the test content includes exercise accuracy, operational thinking time, and overall reaction errors. Finally, by using image processing and analysis techniques on the experimental subjects, the athletic performance of athletes was modeled and the differences in performance between different groups were compared.

Data Evaluation and Result Presentation

Motion Accuracy

The experimental part mainly considered five aspects to verify the accuracy of basketball players' performance: positioning, posture, direction, strength, and dribbling. Through image processing technology, the exercise accuracy of athletes with different levels of motor cognition was investigated, as shown in Tables 2, 3, and 4. R1, R2, R3, R4, and R5 were used to represent positioning, posture, direction, force, and dribbling, respectively.

Table 2

The Exercise Accuracy of Athletes in The Low-Level Exercise Cognition Group in Five Aspects

Number	R1	R2	R3	R4	R5
1	61.92%	61.54%	73.64%	79.66%	78.12%
2	74.04%	67.21%	72.54%	73.33%	70.95%
3	76.20%	77.72%	61.49%	65.49%	64.97%
4	62.38%	73.84%	69.74%	69.38%	64.25%
5	62.40%	77.13%	65.74%	77.04%	69.78%
6	73.28%	71.31%	70.95%	73.62%	73.81%
7	79.77%	76.15%	72.16%	61.20%	78.89%
8	70.99%	66.64%	62.16%	78.70%	79.46%
9	64.46%	68.02%	74.94%	69.56%	67.85%
10	77.33%	68.13%	71.70%	69.25%	72.36%

Table 2 recorded the accuracy rates of athletes in the low-level sports cognition group in terms of positioning, posture, direction, strength, and dribbling. The exercise accuracy of the 10 athletes in the low-level exercise cognition group ranged from 61.2% to 79.77%.

Table 3

The Exercise Accuracy of Athletes in The Medium-Level Exercise Cognition Group in Five Aspects

Number	R1	R2	R3	R4	R5
1	88.22%	84.45%	81.30%	88.41%	88.58%
2	87.64%	85.32%	84.10%	85.68%	81.73%
3	88.40%	86.07%	89.26%	86.00%	81.47%
4	84.08%	82.67%	86.13%	88.81%	82.78%
5	85.49%	88.79%	86.62%	84.04%	87.47%
6	89.50%	87.90%	83.84%	87.09%	88.00%
7	87.46%	83.25%	86.82%	89.27%	84.05%
8	81.33%	80.03%	81.52%	85.56%	83.79%
9	87.92%	83.48%	86.71%	86.07%	82.95%
10	85.14%	81.19%	88.20%	80.58%	81.20%

Table 3 recorded the exercise accuracy of athletes in the medium-level exercise cognition group in five aspects: positioning, posture, direction, strength, and dribbling. The exercise accuracy of the 10 athletes in the medium-level exercise cognition group was distributed between 80.03% and 89.5%.

Table 4

The Exercise Accuracy of Athletes in The High-Level Exercise Cognition Group in Five Aspects

Number	R1	R2	R3	R4	R5
1	99.75%	99.23%	99.01%	98.12%	98.21%
2	99.97%	99.68%	98.84%	99.31%	99.99%
3	99.35%	98.06%	98.84%	98.16%	99.73%
4	99.69%	98.85%	98.07%	98.47%	98.89%
5	99.29%	99.15%	99.31%	98.46%	99.77%
6	98.79%	98.09%	98.59%	99.69%	99.25%
7	98.02%	98.38%	99.53%	98.41%	99.74%
8	98.66%	99.99%	98.53%	99.09%	98.20%
9	98.72%	98.88%	99.77%	98.40%	99.30%
10	98.51%	99.03%	99.44%	99.32%	98.49%

Table 4 recorded the exercise accuracy of high-level sports cognition group athletes in five aspects: positioning, posture, direction, strength, and dribbling. The sports accuracy of the 10 athletes in the high-level sports cognition group ranged from 98.02% to 9.99%.

By comparing the data in Tables 2, 3, and 4, it was found that the higher the level of motor cognition, the higher the accuracy of motor performance.

According to the data in Tables 2, 3, and 4, the average accuracy rates of athletes with different levels of motor cognition in terms of positioning, posture, direction, strength, and dribbling were calculated, as shown in Figure 9.

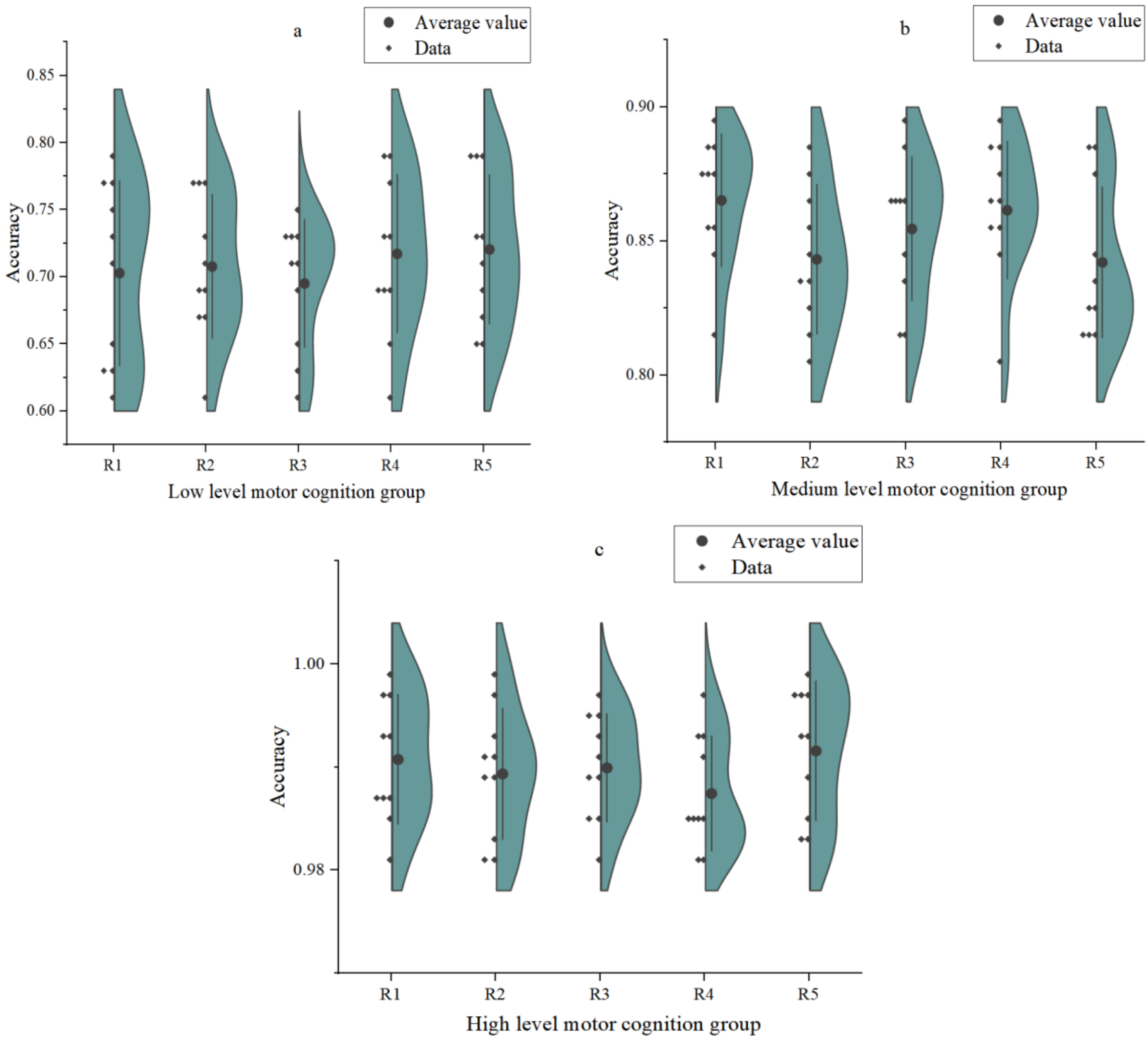

Figure 9: Mean Graph of Exercise Accuracy In 5 Aspects of Athletes in The Sports Cognitive Level Group.

Figure 9 (a) Mean of exercise accuracy in 5 aspects for athletes in the low-level exercise cognition group

Figure 9 (b) Mean of exercise accuracy in 5 aspects for athletes in the medium-level exercise cognition group

Figure 9 (c) Mean of exercise accuracy in five aspects for athletes in the high-level sports cognition group

Figure 9 refers to the average accuracy chart of athletes in the sports cognitive level group in five aspects, while Figure 9 (a) describes the average accuracy chart of athletes in the low-level sports cognitive level group in terms of positioning, posture, direction, strength, and dribbling. The average accuracy of low-level sports cognition group athletes was highest in dribbling and the lowest in direction. Among them, the average accuracy rates of athletes in the low-level sports cognition group in terms of positioning, posture, direction, strength, and dribbling were 70.28%, 70.77%, 69.51%, 71.72%, and 72.04%, respectively.

Figure 9 (b) depicts the average accuracy of movement in terms of positioning, posture, direction, strength, and dribbling among athletes in the cognitive group of medium-level movement. The average accuracy of athletes in the medium-level sports cognition group was highest in positioning, while the lowest average accuracy was in dribbling. The average accuracy rates of positioning, posture, direction, strength, and dribbling for athletes in the medium-level sports cognition group were 86.52%, 84.32%, 85.45%, 86.15%, and 84.2%, respectively.

Figure 9 (c) depicts the average exercise accuracy of athletes in the high-level sports cognition group in terms of positioning, posture, direction, strength, and dribbling. The athletes in the high-level sports cognition group had the highest average sports accuracy in dribbling, while the lowest average sports accuracy was in strength. The average accuracy rates of athletes in the high-level sports cognition group in terms of positioning, posture, direction, strength, and dribbling were 99.08%, 98.93%, 98.99%, 98.74%, and 99.16%, respectively.

The mean graph in Figure 9 showed that the athletes in the high-level sports cognition group had higher sports accuracy in all aspects compared to the other two groups of cognitive level athletes, while the athletes in the medium-level sports cognition group had higher sports accuracy in all aspects compared to the athletes in the low cognitive level athletes. These results indicated that cognitive ability was directly proportional to exercise accuracy.

Operation and Thinking Time

The operating thinking time of athletes in sports performance can be used as one of the indicators to effectively test the relational model between cognitive ability and sports performance. The shorter the operational thinking time, the better the athletic performance. Similarly, 10 athletes from different levels of sports cognition groups were assigned shooting positions in the same scene. The thinking time of shooting positioning operation of each player in different groups was recorded, as shown in Figure 10.

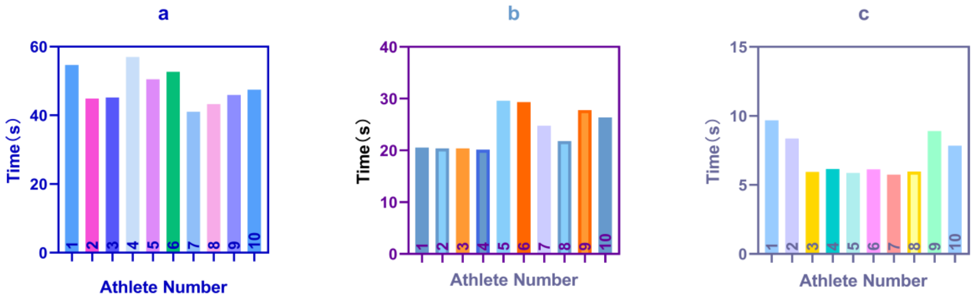

Figure 10: Thinking Time of Shooting Positioning Operation of Athletes in Different Sports Cognitive Levels.

Figure 10 (a). Thinking time of shooting positioning operation of athletes in the low-level sports cognition group

Figure 10 (b). Thinking time of shooting positioning operation of athletes in the medium-level sports cognition group

Figure 10 (c). Thinking time of shooting positioning operation of athletes in high-level sports cognition group

Figure 10 shows the shooting positioning operation thinking time of 10 athletes in different sports cognitive groups, and Figure 10 (a) represents the shooting positioning operation thinking time of 10 athletes in the low-level sports cognitive group. The thinking time of shooting positioning operation of 10 athletes in the low-level sports cognition group was relatively long as a whole, and the thinking time of shooting positioning operation was mainly distributed between 41.03 seconds and 56.98 seconds.

Figure 10 (b) represents the shooting positioning operation thinking time of 10 athletes in the medium-level sports cognition group. The thinking time of shooting positioning operation of 10 athletes in the medium-level sports cognition group was shorter than that in the low-level sports cognition group as a whole, and the thinking time of shooting positioning operation was mainly distributed between 20.15 seconds and 29.57 seconds.

Figure 10 (c) represents the shooting positioning operation thinking time of 10 athletes in the high-level sports cognition group. The thinking time for shooting positioning operation of 10 athletes in the high-level sports cognition group was very short as a whole, and the thinking time for shooting positioning operation was mainly distributed between 5.74 seconds and 9.68 seconds. According to Figure 10 (a), Figure 10 (b) and Figure 10 (c), it was concluded that the thinking time of shooting positioning operation of 10 athletes in the medium sports cognitive level group was shorter than that in the low sports cognitive level group. However, this took longer than the high-level motor cognition group.

The thinking time of shooting positioning operation of each player in the high-level sports cognition group was relatively close, and the difference was not significant. The maximum difference was 3.94 seconds. The maximum difference of thinking time of shooting positioning operation of each player in the medium-level sports cognition group was 9.42 seconds. The maximum difference of thinking time of shooting positioning operation of each player in the low-level sports cognition group was 15.95 seconds.

Whether it was to analyze the length of thinking time of shooting positioning operation or the difference of thinking time of each team member, the high-level sports cognition group had the greatest advantage in sports performance.

Comprehensive Reaction Errors

Comprehensive response error refers to an index that reflects acceptance ability, perceptual sensitivity, concentration and allocation of attention, accuracy and flexibility of coordinated responses.

Ten athletes from different levels of sports cognition were assigned 10 basketball training sessions, and the comprehensive reaction error index of each group of athletes was recorded, as shown in Table 5.

Table 5

Comprehensive Response Error Index of Groups with Different Motor Cognitive Levels

Number Cognitive ability	T1	T2	T3
1	0.73	1.10	3.64
2	0.50	1.45	3.78
3	1.04	1.42	3.29
4	0.28	1.47	3.30
5	0.78	1.21	3.33
6	0.82	1.59	3.81
7	0.13	1.57	3.82
8	0.12	1.69	3.60
9	0.95	1.37	3.32
10	0.62	1.46	3.44

The comprehensive reaction error index recorded in Table 5 for each group of athletes was as follows: the comprehensive reaction error index for 10 basketball training sessions in the low-level sports cognition group ranged from 0.12 to 1.04; the comprehensive response error index of the 10 basketball training sessions in the medium-level sports cognition group ranged from 1.1 to 1.69; the comprehensive response error index of the high-level sports cognition group during 10 basketball training sessions ranged from 3.29 to 3.82. According to the data in Table 5, the average comprehensive response error index for three different cognitive abilities levels was calculated, as shown in Figure 11.

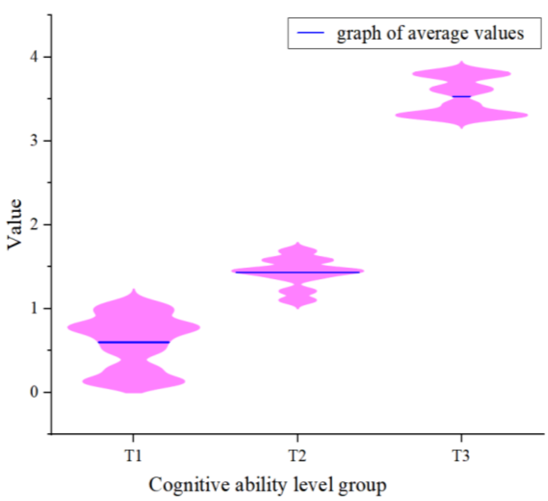

Figure 11: Mean Comprehensive Response Error Index for Groups with Different Cognitive Levels.

Figure 11 shows the mean line of the comprehensive response error index for groups with different cognitive levels. It was obvious that the group with high-level motor cognitive ability had the highest average comprehensive response error index. The second group was the medium-level motor cognitive ability group, and the third group was the low-level cognitive ability group.

The experimental results indicated that the cognitive ability of athletes was closely related to their sports performance, and good cognitive ability could improve their sports performance. Therefore, this experiment provided a scientific basis for exploring the relationship between athletes' cognitive ability and sports performance and provided technical support for optimizing athletes' training strategies.

Conclusions

This article mainly analyzed and modeled the relationship between athletes' cognitive ability and sports performance through image processing technology. The experiment involved athletes from different sports cognition groups, assessing their exercise accuracy, operational thinking time, and overall reaction errors. The results showed that athletes in the high-level sports cognition group excelled, achieving exercise accuracy percentages ranging from 98.02% to 99.99% and displaying the lowest comprehensive response error index with an average of 3.533, ranging from 3.29 to 3.82. In contrast, the medium-level sports cognition group exhibited moderate exercise accuracy and an average comprehensive response error index of 1.433, ranging from 1.1 to 1.69. The low-level sports cognition group recorded the lowest exercise accuracy and had a comprehensive response error index averaging 0.597, with individual scores ranging from 0.12 to 1.04. These findings clearly demonstrate that higher cognitive abilities correlate with improved motor performance, suggesting that training to enhance cognitive abilities can significantly boost athletic performance. This study provides a new theoretical basis for understanding the relationship between cognitive ability and sports performance, offering innovative ideas and methods for athlete training and competition.

Author Contributions

Conceptualization: J.Z. and J.L.; methodology: R.L. and Z.Y.; formal analysis: J.Z. and Z.Y; investigation: M.R. and J.Z.; resources: J.Z.and R.L.; writing—original draft preparation:J.Z.; writing—review & editing: J.Z. and J.L. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data is available in the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Consent to Participate Declaration

All participants provided their informed consent prior to their inclusion in the study. Participants were informed about the purpose of the study, the procedures involved, and their right to withdraw at any time without any consequences

Ethics Declaration

The study was conducted in accordance with the Declaration of Helsinki.

Human Ethics and Consent to Participate declarations

Not applicable. The risk to participants in this study does not exceed the minimum threshold, and it does not involve any potentially harmful sensitive information or interventions. Therefore, this study does not require ethical approval.

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