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Influence of VR-Assisted College Dance on College Students' Physical and Mental Health and Comprehensive Quality

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ABSTRACT

With the development and the popularization of sports dance, sports dance teaching has become a required elective course in universities. Sports dance can not only improve students' comprehensive quality, but also affect college students' healthy psychology. The use of VR (Virtual Reality) technology in dance education will definitely develop and promote dance education. This paper studies an effective feature extraction method for the characteristics of dance movements based on VR. The edge features of all video images in each segment are accumulated into one image, and the directional gradient histogram features are extracted from it. The results show that compared with the current robust regression method and cascade regression method, our method has higher positioning accuracy on the pollution test set, and more than 75% of the sample errors in this method are within 0.1. This also verifies the effectiveness of this motion recognition algorithm for dance motion recognition. Dance can effectively resist the psychological barriers of college students and improve their comprehensive quality.

KEYWORDS

College Students, Comprehensive Quality, Mental Health, Sports Dance, VR

INTRODUCTION

In today's society, sports dance, as an activity that integrates sports competition and dance art, is gradually receiving widespread attention from people. It not only demonstrates the competitiveness of sports, but also contains rich cultural and artistic values, making it a unique sports event. However, despite the potential positive effects of sports dance in improving personal physical and mental health and overall quality, there is still limited research on its impact on the mental health of college students, especially the lack of scientific research to explore the actual effects of sports dance on promoting the mental health of college students. In view of this, in this study the authors aimed to explore the impact of introducing sports dance into public physical education courses in universities on the physical and mental health and overall quality of college students. Through in-depth analysis of the role of sports dance teaching in improving the physical self-esteem, mental health status, and

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meeting the social demand for high-quality talents of college students, the authors sought to provide theoretical basis and practical guidance for the development of sports dance education. The authors adopted a template-based recognition method, which extracts key frames of motion sequences and matches these motion feature data with standard motion data in the database, achieving accurate recognition of the motion to be recognized. The results indicate that virtual reality (VR) technology is of great help in the field of dance education, providing new possibilities for dance teaching and learning. The application of VR technology can not only solve some of the challenges currently faced by dance art education, such as space limitations and insufficient resources, but also help promote the long-term development of dance art, improve the level of dance education, and enable more people to enjoy the fun and beauty brought by dance. This study provides scientific basis for the teaching and popularization of sports dance, promotes the development of the field of sports dance, and improves the physical and mental health and comprehensive quality of college students.

LITERATURE REVIEW

With the improvement of people's awareness that sports can promote and improve mental health, more and more scholars have gradually enriched their research on specific sports. At present, sports dance has become an important part of the sports and cultural life among teachers and students in universities in China, with frequent interschool competitions and exchanges have taking place. Among them, there are many research studies on the physiological and psychological influences, which play a positive role in promoting and guiding the development of sports dance in China.

Hung et al. (2024) pointed out that sports dance can meet people's psychological needs, improve the content of national fitness activities, promote physical and mental health, and enrich cultural life. Romeo et al. (2024) proposed that sports dance can effectively regulate the central nervous system of the human body and play a good role in preventing various neurological diseases. Jung et al. (2024) concluded that sports dance can effectively improve the physical self-esteem of ordinary college students. It can effectively reduce the negative factors in their mental state, help to improve their mental state, and promote their mental health.

Jiang and Yan (2024) put forward eight standards for college students' mental health, namely, normal intelligence, coordinated control of emotions, strong will, age-appropriate mind, harmonious interpersonal relationship, adaptation to social life, love of life, and complete and harmonious personality structure. Han and Zhang (2024) divided dance therapy objects into three categories: Children, adults, and the elderly. Dance can help the elderly rejuvenate, keep healthy, and prevent the occurrence of autism in the elderly. According to Tsuchida et al. (2024), college students' interpersonal relationship is the psychological relationship between college students in their study, life, and work.

In recent years, a large number of domestic and foreign scientific research institutions and related scholars have devoted themselves to the research of motion recognition based on video, which has made great contributions to the development of motion recognition research (Averill et al., 2024). By using the shape coding scheme, the human body contour in the data frame is obtained and the characteristic data of the human body contour are extracted, and then the segmentation is completed by detecting the change of the intrinsic dimension.

Rubio-Arias et al. (2024) extracted human motion shape information to represent motion edge information through Canny edge detection, and then achieved the purpose of human motion recognition by matching similar edges. Zhang and Wang (2024) changed the traditional way of training separately and combining attitude estimation and motion recognition in sequence, and put forward a framework of combining attitude estimation and motion recognition. The accuracy of motion recognition has reached the first-class standard, and the attitude estimation has been improved. Greco (2024) introduced a linear time-invariant system to extract key frames. This method is similar to clustering. First, high-dimensional motion data are mapped to low-dimensional ones. Then, the rule of sum of squares of errors and the similarity measure between defined poses are used to segment the low-dimensional data, and the key frames are selected as the points with the greatest changes. Sarakatsanos et al. (2024) mapped high-dimensional motion data into low-dimensional Euclidean space through transformation, and then extracted key frames by curve simplification method. The calculation of this method is very complicated, some information will be lost due to mapping, and the efficiency is also low, which ultimately affects the representation effect of key frames.

Peng (2024) used gradient direction histogram to calculate the apparent information of human body, forming many feature vectors, and then used principal component analysis to reduce the dimensions of these feature vectors. Han and Zhiyu (2024) reviewed and compared the methods based on local spatio-temporal features and visual dictionary interpretation, and proposed a simple and effective representation method-mixed representation, which showed good performance on many action data sets. Xie and Li (2024) put forward an improved method to extract multiscale convolution feature map by using double-stream convolution network. This scheme encodes deep features into effective descriptors constrained by sampling trajectory, which can effectively collect information for a long time. Peinado-Rubia et al. (2024) built a motion recognition model based on recurrent neural network (RNN) and long short-term memory, which used different levels of attention to learn the distinguishing joints of bones in each input frame.

RELATED MATERIALS AND METHOD

Sports Dance Teaching

Dance education is a comprehensive discipline that combines art and sports, aiming to cultivate students' physical coordination, musical rhythm, artistic expression, and creativity through the learning and practice of dance (Prudente et al., 2024). It not only focuses on the training of dance techniques, but also emphasizes the understanding and appreciation of dance as a cultural and artistic form. The application of VR technology in dance education provides innovative ways to solve multiple problems in current dance art. For students who are geographically remote or unable to access professional dance classrooms, VR technology provides a possibility to learn dance in virtual space, breaking geographical limitations. VR can create virtual dance studios, allowing students to practice and learn without the need for physical space, which is very useful for situations with limited space. VR technology can simulate real stage environments, allowing students to practice performing without actual performance pressure, which helps to enhance their expressive power and confidence. In a virtual environment, students can safely try new dance movements or techniques without worrying about the risk of injury, which is particularly important for learning difficult movements. In summary, the application of VR technology in dance education provides a new perspective and method for solving the problems faced by current dance art. It can not only improve learning efficiency, break geographical limitations, and enhance creativity and expressiveness, but also provide accurate action feedback while ensuring the safety of the learning process. With the continuous development and improvement of technology, the application of VR in dance education will be more extensive and in-depth.

The application of VR technology in dance education has brought various benefits to educators and learners, including improving teaching effectiveness, increasing learning motivation, expanding learning resources, and innovating teaching methods. VR technology provides teachers with a new teaching tool that can impart dance skills and theoretical knowledge in a more vivid and interactive way, thereby stimulating students' interest in learning (Kashif et al., 2024). By utilizing VR technology, teachers can provide personalized guidance and feedback based on the learning progress and needs of each student, thereby improving teaching effectiveness (Li, 2024). Through VR, teachers can introduce dance styles and techniques from around the world, allowing students to experience and learn dance from different cultures without physical limitations. VR technology can help teachers demonstrate complex dance movements and techniques to students in a short period of time, while also reducing the time and resources required to prepare for actual demonstrations (Gkintoni et al., 2024). In addition, VR technology provides an immersive environment that allows students to fully immerse themselves in dance learning, which helps improve learning efficiency and memory. When learning new dance moves, students may worry about getting injured. VR provides a low-risk environment where students can freely try and practice without worrying about getting injured (Herrmann et al., 2024). Some VR dance applications can provide real-time motion feedback and correction guidance, helping students master the correct dance techniques faster. The novelty and interactivity of VR technology can enhance students' interest and participation in learning, especially for those who are difficult to attract with traditional teaching methods (Devine et al., 2024). VR enables students to receive dance education at home or anywhere, breaking geographical limitations and making it particularly suitable for students who cannot easily access dance schools or studios (Lavoie et al., 2024). Through the VR platform, students can learn and practice according to their own pace, which encourages the spirit of self-directed learning and helps them develop self-driven learning habits (Russell, 2024). In short, integrating VR technology into dance education can not only provide teachers with powerful teaching tools and enhance the diversity and efficiency of teaching methods, but also create a more dynamic, interactive, and personalized learning environment for students, thereby improving learning effectiveness and experience (Minaoglou et al., 2024).

At present, there is little research on the effect of sports dance on college students' mental health, and the scientific research on the actual effect of sports dance on promoting college students' mental health is rare. Therefore, it is of great significance to study the influence of sports dance on college students' physical and mental health and comprehensive quality in university public physical education class, and the results will be of great significance to improve the cognitive level of college students' physical self-esteem, improve their mental health, and better meet the needs of society by using sports dance teaching.

Dance is a way of expressing emotions, conveying inner emotions through body movements, postures, and body language. Dance allows college students to express their emotions, release stress and negative emotions, and alleviate psychological barriers through dance. Dance requires physical movement and coordination, and, through movements such as jumping, turning, and dancing, it can help college students adjust their physical and mental states and enhance their physical and mental connections. Dance allows college students to focus on their physical sensations and movements, thereby reducing mental stress and achieving a relaxing effect on both body and mind. Dance is usually conducted in groups, and college students participating in dance can cultivate social skills and teamwork spirit. Dance provides a social platform for college students to interact, communicate, and collaborate with others, thereby reducing loneliness and increasing social support, which has a positive impact on psychological disorders. Through dance practice and performance, college students can enhance their sense of self-identity and confidence. Dance allows college students to feel their growth and progress, cultivate a positive self-image, and enhance their psychological resilience and ability to resist psychological barriers. Dance, as a form of physical activity and art, has a positive effect on college students in coping with psychological disorders. We encourage college students to try dance activities to promote mental health.

In addition, dance has a significant impact on the overall quality improvement of college students. Dance requires a certain amount of physical strength, flexibility, and coordination. Through dance training, college students can improve their physical fitness, including enhancing muscle strength, improving flexibility and balance abilities. This helps to improve physical health and enhance the ability to resist diseases. Dance can help college students relieve stress, alleviate anxiety and depression, and improve their psychological quality. The movements and music of dance can bring a joyful feeling, promote the generation of positive emotions, enhance self-confidence and an optimistic attitude. In addition, through dance performances and interactions, college students can also cultivate social skills and teamwork awareness, enhance social support and interpersonal relationships. Dance is an art form, and, through learning dance, college students can cultivate their aesthetic ability and artistic cultivation. They can appreciate and understand different types of dance works, improving their perception of music and stage performance. This helps to broaden one's horizons, enrich cultural literacy, and cultivate a love and pursuit of art. Dance can help college students better understand their bodies and emotions, and express themselves through dance. Through dance training and performance, college students can discover their potential and characteristics, cultivate self-confidence and self-identity. Meanwhile, dance can also enhance the creativity and expression ability of college students, enabling them to convey ideas and emotions through dance. In short, dance has a comprehensive impact on the overall quality improvement of college students, including physical fitness, psychological quality, artistic cultivation, as well as self-awareness and expression ability. These improvements will help college students develop and showcase themselves more comprehensively in their studies, lives, and social interactions.

Integrating VR technology into dance education is a cutting-edge and challenging field that aims to enhance learning outcomes, increase student engagement, and provide new perspectives for dance learning through immersive experiences. However, there may be some challenges in the actual integration process:

1. **Cost and Accessibility of Technical Equipment:** VR devices and software typically require a high initial investment, which may be a barrier for educational institutions with limited budgets. They should consider finding cost-effective VR devices and open-source software. In addition, they could raise funds through partnerships or sponsors. Finally, they should set up shared VR sites in the course to reduce the number of devices required for each student.
2. **Technology Adaptation and Training:** Teachers and students may not be familiar with VR technology and require time and resources to learn how to effectively use these tools. Educational institutions should provide specialized VR technology training courses for teachers and students, create easy to understand user guides and online tutorials, and establish a technical support team to assist in resolving any issues encountered during use.
3. **The Physical Interaction Limitations of Dance Learning:** Virtual environments may not be able to fully replicate physical contact and spatial perception in the real world, which is crucial for certain elements in dance education. Educational institutions should combine VR with dance exercises in the real world to ensure that students can acquire necessary physical perception and muscle memory, utilize advanced VR technologies (e.g., spatial tracking and tactile feedback devices) to enhance user spatial perception and physical interaction, and develop more advanced VR dance applications that can simulate real dance movements and interactions.
4. **Development and Customization of Learning Content:** Developing high-quality and interactive VR dance education content requires much time, professional knowledge, and resources. Educational institutions should collaborate with professional VR content developers to jointly develop dance teaching materials that meet educational goals. They should encourage teachers and students to participate together in the creation and customization of VR teaching content to ensure its relevance and effectiveness. Also, they should utilize artificial intelligence (AI) technology to automatically generate or personalize learning content.

The overview of these challenges and solutions evidences that, although integrating VR technology into dance education raises certain challenges, they can be overcome through innovation and reasonable planning. Implementing these solutions will help maximize the potential of VR technology in dance education and provide students with a unique and effective learning experience.

With the continuous advancement of VR technology, future dance education will be able to provide a more immersive and authentic learning experience. Students can immerse themselves in a fully simulated stage environment, practice with virtual dance partners, and even explore different dance styles and cultures without physical limitations. This immersive experience helps improve learning motivation and efficiency. By integrating AI and VR, dance education platforms can provide personalized learning paths based on students' abilities and preferences. The system can analyze students' performance in real-time, provide targeted feedback and guidance, and thus achieve adaptive learning. This will ensure that each student can learn at the most suitable speed and method, maximizing learning outcomes. In the future, remote dance education will become more popular and efficient, and students will be able to interact with remote teachers and classmates in real-time through VR helmets and sensors, enjoying a nearly face-to-face learning experience. VR technology provides new possibilities for dance creation and performance. In addition, through VR, audiences can experience dance works in new ways, such as watching performances from the dancer's perspective, or freely moving in virtual space to explore different viewing angles. The development of VR technology will promote the integration of dance with other art forms (e.g., music, visual arts, and drama) and promote interdisciplinary art education. Students can explore and experiment with the combination of different art forms in a virtual environment, stimulating innovative thinking and creativity.

Dance Action Capture Based on Virtual Reality Technology

The feature extraction of dance movements based on VR technology is a complex process involving computer vision, AI, and sensor technology. The goal of this process is to accurately capture, analyze, and understand the movements of dancers for further learning, evaluation or creation. The following are key steps to achieve this goal:

1. **Data Capture:** Using VR sensors and tracking devices, real-time motion data of dancers are captured through VR sensors equipped on the dancers (e.g., motion tracking suits, gloves, and helmets) and tracking cameras in the environment. These devices can accurately record information (e.g., the dancer's position, speed, and acceleration). An optical tracking system uses high-speed cameras and marker points to capture the three-dimensional movement of dancers, and records actions by analyzing the movement of marker points.
2. **Data Preprocessing**: Filtering and denoising, and filtering and processing captured action data are used to remove noise and improve data quality.
3. **Normalization processing:** In order to eliminate the impact of body shape differences between different dancers on motion analysis, it is necessary to normalize the data.
4. **Action Feature Extraction:** Key point detection, recognition, and extraction in dance movements (e.g., wrist, elbow, knee, and other joint positions), and the motion trajectory of these key points are crucial for understanding dance movements. Attitude estimation, based on key point data and using deep learning models, allows to estimate the dancer's posture. This includes the direction and relative position of various parts of the body. Action sequence analysis breaks down continuous dance movements into a series of meaningful action units, each representing a specific dance action or step.
5. **Action Understanding and Classification:** Deep learning and machine learning algorithms utilize deep learning (e.g., convolutional neural network, RNN, and machine learning algorithms such as support vector machine) to analyze the extracted features, in order to understand and classify dance actions. Action pattern recognition achieves automatic recognition and classification of actions by comparing extracted action features with predefined action templates or actions in databases.

In the proposed feature extraction methods, accumulating edge features and extracting histogram of oriented gradient (HOG) features are commonly used for image processing and target recognition tasks, such as pedestrian detection and object recognition. The following is a brief process for accumulating edge features:

1. **Edge Detection:** Edge detection is performed on the input image, in order to accurately find the edge information in the image. Commonly used methods include Sobel operator, Prewitt operator, and Canny edge detection.

2. **Accumulate Edge Direction:** Based on edge detection, the edge direction at each pixel point can be calculated. Usually, gradient operators are used to obtain the gradient amplitude and direction of each pixel.
3. **Edge Direction Integration:** In order to accumulate edge features, it is necessary to integrate or accumulate the edge direction information of each pixel in the image in a local area. This can better capture the distribution and direction of edges.

The general process of extracting HOG features is as follows:

1. **Image Unit Division:** The image is divided into multiple small cells, usually using square cells. Each cell contains multiple pixels.
2. **Gradient Calculation:** The gradient amplitude and direction for each pixel within a cell is calculated. Usually, Sobel operators or other gradient operators are used for calculation.
3. **Direction Histogram Statistics:** The pixel gradient direction of each cell is projected onto a fixed number of direction intervals (bin), and then the sum of gradient amplitudes is calculated within each direction interval. This can produce a histogram representing the gradient direction distribution of the cell.
4. **Block Normalization:** Combining adjacent cells into a block, the histogram is normalized within the block to reduce the impact of lighting changes and shadows.
5. **Feature Vector Concatenation:** The normalized histograms are concatenated within all blocks to form the final HOG feature vector. This feature vector can be used to train machine learning models for object detection and recognition.

Through these steps, features with edge and texture information can be effectively extracted from the image for subsequent target recognition, detection or classification tasks. These features are widely used in the field of computer vision and have demonstrated good performance and robustness in many tasks.

Motion capture technology mainly collects data about the length of the main joints of the performance object's body and the angle of joint movement, and makes use of virtual display and other display technologies to convert these data into intuitive images. Sports data, as the basis for distinguishing the composition of movements in the collection of pure cultural resources, have not been applied to the in-depth analysis of the intrinsic characteristics of this kind of dance. Dance is different from the physical movements of images in ordinary games and movies, so it needs more efficient and high-precision gesture recognition to form a practical and effective method, provide stable and accurate analysis, and form a good theoretical support.

Gait analysis is a method used to study the treatment and rehabilitation effects of orthopedic diseases. It uses mechanical concepts and algorithms to analyze the kinematics and dynamics of human limbs and joints when walking. The first step to generate a VR video is for dance teachers to determine the teaching content. Whether it is oral theoretical knowledge or dance demonstration, teachers need to wear motion capture clothes with mark points to capture the motion, record them into 360-degree videos, and then generate a VR video. VR technology allows to use the 360 viewing angle to change the viewing angle and see clearly. It is also a more practical solution for mass users, and researchers have been working in this area all the time. It keeps the latest target appearance model through dynamic updating in the tracking process. This method can deal with some partial occlusion situations and improve the long-time tracking performance.

For the human hand, the minimum requirement must also meet that each joint has three degrees of freedom displacement and three degrees of freedom rotation. Generally, at least 14 inertial sensors are used, and each sensor collects data related to the displacement of three degrees of freedom and the rotation of three degrees of freedom of each bone. When the data of a joint are imported into the computer, an array is built based on the joint, and the values of X,Y,Z of displacement, rotation, and scaling are stored as an array with three rows and three columns, as in Equation 1:

$$Joint = \begin{bmatrix} tx & ty & tz \\ rx & ry & rz \\ sx & sy & sz \end{bmatrix} \tag{1}$$

where tx,ty,tz is the value of displacement X,Y,Z , rx,ry,rz is the X,Y,Z value of rotation, and sx,sy,sz is the X,Y,Z value of scaling.

Because the range of eigenvalues is different, in order to compare the variation rules of different feature groups, the feature information is normalized. The common methods are linear function conversion, trigonometric function conversion, logarithmic function conversion, and probability distribution. In this study, the authors used linear function to normalize the original input and output data to the range of [0,1]. Equation 2 shows the specific conversion:

$$y = \frac{x - x_{MinSensor}}{x_{MaxSensor} - x_{MinSensor}} \tag{2}$$

where x,y is the value before and after conversion and $x_{MinSensor}, x_{MaxSensor}$ is the maximum and minimum value of the collected data. There is a one-to-one correspondence between the normalized output of the sensor and the joint angle. Therefore, the electrical output signal of the sensor and the joint angle are calibrated.

Compared with the rotation matrix method, the quaternion method can represent the rotation of the coordinate system with only four elements, which can improve the computational efficiency:

$$q = q_0 + q_1 i + q_2 j + q_3 k \tag{3}$$

where i,j,k is the standard orthogonal basis of European space, q_0 is a scalar in quaternion, and $\left(q_1, q_2, q_3\right)^T$ is the direction vector in quaternion.

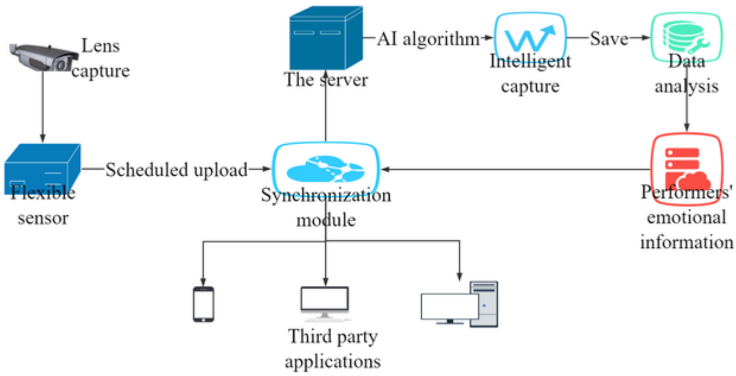
Based on the feature that the flexible sensor can be worn close to the body, it can effectively collect the changes of the performer's physical signs in the performance process, and help to strengthen the understanding of the style characteristics such as static, dynamic, and overall posture under multiangle reconstruction.

The accumulated apparent changes in the tracking process will lead to the tracking drift of the traditional sparse tracking method. When the brightness of the shelter is lower than the tracking target, it is easy to make false judgment of occlusion, and the target is often lost after occlusion. However, only when the current image is close to the target, only some feature templates can be used to fit the image well. Figure 1 shows the process of VR-assisted dance motion capture.

By using 17 inertial dynamic capture nodes, the attitude measurement range is 360 degrees, the acceleration range is 8g, the angular velocity range is 2 000dps, the angle measurement resolution is 0. 02deg, and the maximum update rate is 200fps. During walking, it is necessary to ensure that the subject walks along a straight line as much as possible and walks naturally.

After walking, four gait cycles of the subject are formed in the computer, and analysis samples are formed, thus preparing for the subsequent data analysis. These include their standing phase, swinging phase, and weight-bearing period of both limbs. With these data as reference, a preliminary

Figure 1. Dance Action Capture Process



evaluation of the subject's gait cycle can be made, and a score can be given for the gait analysis of the subject, so as to give the rehabilitation result.

Given that data pollution and outliers are ubiquitous in practical applications, how to recover pure data is crucial for robust regression. Compressing high-dimensional data into dimensional subspace is the most useful example of subspace recovery. Principal component analysis estimates these two parts by minimizing the weighted combination of kernel norm and 1 norm, which are defined as follows:

$$\begin{aligned} &\min \left\|D\right\|_{*} + \lambda \left\|E\right\|_{1} \\ &s.t.\ X = D = E \end{aligned} \tag{4}$$

where $X \in R^{m \times n}$ is the data set composed of observation samples, D represents a pure data matrix distributed in a low-dimensional subspace, and each column is a sample, and E can be considered as the deviation of X from the intrinsic low-dimensional subspace.

Two-dimensional projection constraints need to be further introduced to solve the coefficients based on two-dimensional images. Because it is not feasible to calculate all pixel correspondences, projection constraints are usually applied to a set of predefined face key points. Equation 5 shows the projection migration model from 3D point to 2D key point:

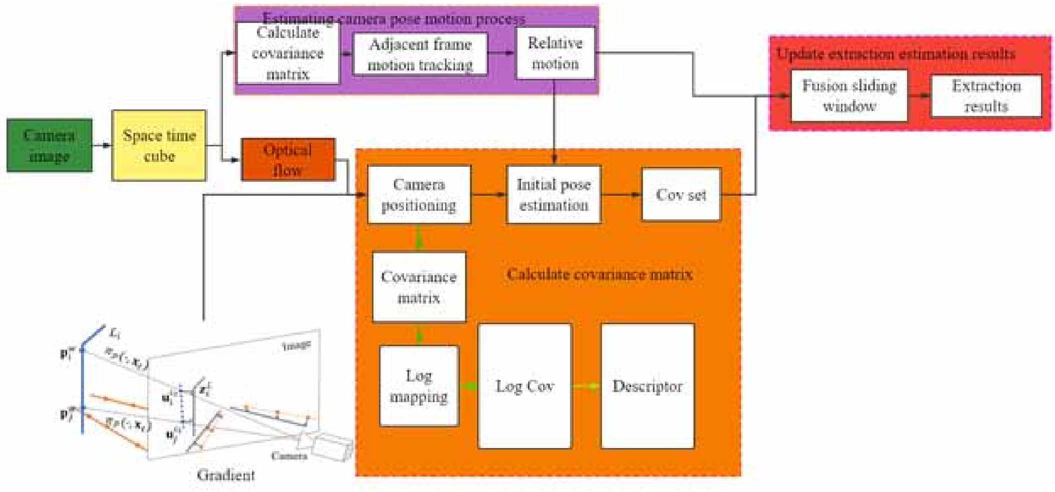
$$d_k = s_k - \prod\nolimits_Q \left(F^{(v_k)}\right) \tag{5}$$

where s_k is the key point of image positioning, $F^{(v_k)}$ is the predefined corresponding vertex on the 3D model, d_k is the projection offset, and $\prod_Q$ is the image projection operation based on perspective projection matrix Q.

Feature Fusion and Identification of College Sports Dance

The action recognition algorithm needs to select appropriate features to describe dance movements, in order to accurately determine the type and characteristics of dance movements. Choosing appropriate features is crucial for improving the accuracy and stability of action recognition algorithms. Action recognition algorithms need to have real-time performance and be able to adapt to different application scenarios. For example, in dance competitions, motion recognition algorithms need to be able to accurately recognize and rate dance movements, while, in the field of medical rehabilitation,

Figure 2. Schematic Diagram of Local Feature Extraction Based on Covariance Matrix



motion recognition algorithms need to be able to monitor and correct body posture and movements. Therefore, action recognition algorithms need to be optimized and adaptively designed for different application scenarios.

Efficient feature extraction of human motion in video is only the key first step in video motion recognition. After feature extraction, it is also the key second step in motion recognition, that is, modeling the motion, and finally recognizing the motion in video. The template matching method has low computational complexity, high computational speed and high efficiency, because it only needs to calculate the distance between the template action table and the action to be measured or the similarity between the two measures. However, choosing the time interval of action video is a difficult point of this kind of algorithm. Moreover, there are a variety of human postures in dance movements, and it is difficult to obtain the requirements of the actor's complete front or back in monocular situations. Therefore, the adaptability of motion recognition only relying on human posture information is poor.

Thus, in this study, although the authors also used the position of the main joints of the human body generated by pose estimation to determine the image area of the human body, they adopted the template-based recognition method, extracted the key frames of the motion sequence by the method mentioned above, and matched the extracted motion feature data with the standard motion data in the database, so as to realize the recognition of the motion to be recognized (Figure 2). This is equivalent to mapping each three-dimensional data block in the video to a point in Riemannian manifold where the symmetric positive definite matrix space is located.

It should be noted that, because the cross-section size of the cube is two to three times of the grid size, when dividing the grid in the previous step, the start should not be from the boundary of the grayscale image, but should have a certain deviation from the boundary. Therefore, when dividing the starting point of the grid horizontally, the deviation p_l from the left boundary of the grayscale image is as in Equation 6:

$$\begin{cases} p_l = \left[c/2\right] + \left[r/2\right] + 1 \\ r = \mathrm{mod}\left(w - c, g\right) \end{cases} \tag{6}$$

After dividing the grid, the number of remaining pixels r in the horizontal direction of the grayscale image is $\operatorname{mod}\left(w-c,g\right)$, where $\operatorname{mod}\left(\ \right)$ is the complementary operator. Similarly, the number of remaining pixels r in the vertical direction of the image is $\operatorname{mod}\left(w-c,g\right)$. This is the reason why the width w of the image is reduced by the side length c of the space-time cube.

At present, the simplest way to combine multiple kernel functions is linear combination. Therefore, in multicore learning, most of the established multicore models form a new kernel function by linear combination of multiple kernel functions. The linear kernel function representation is as follows:

$$k\left(x,z\right)=\sum_{j=1}^{M}\beta_j k_j\left(x,z\right),\beta_j\geq 0,\sum_{j=1}^{M}\beta_j=1 \tag{7}$$

where M represents the number of kernel functions, $k_j\left(x,z\right)$ is the kernel function, and β_j is the weight corresponding to the kernel function.

In the dynamic time warping algorithm, in order to logically align the two sequences to be compared, it is necessary to construct a sequence distance matrix D according to the distance between the frames of the two sequences.

The rows of the matrix correspond to the action sequence T to be identified and the columns of the matrix correspond to the standard action sequence R. The matrix $\left(i,j\right)$ is the Euclidean distance between the positions of two frames of action data of the action sequence $T\left(i\right)$ to be identified and the standard action sequence $R\left(j\right)$ in the corresponding row and column:

$$d\left[T\left(i\right),R\left(j\right)\right]=\sqrt{\sum_{k=1}^{K}\left[T\left(ik\right)-R\left(jk\right)\right]^2},\quad 1\leq k\leq K \tag{8}$$

where $T\left(ik\right)$ represents the relative position of the k th joint point corresponding to the i -th frame action sequence in sequence T, $R\left(jk\right)$ represents the relative position of the k th joint point corresponding to the j -th frame action sequence in sequence R, and K represents the number of joint points of motion capture data.

The light flow uses the variational method to calculate the displacement vector field d_t of the pixel $\left(x,y\right)$ between two consecutive frames at time $t,t+1$ and find the function u,v that minimizes the energy function. The mathematical expression for optimizing the global energy function composed of data terms and smooth terms in optical flow calculation is as follows:

$$E_{Global}=E_{data}+\lambda E_{smooth} \tag{9}$$

where E_{data} is the data item, which measures the consistency between the optical flow and the input image, E_{smooth} is the smoothing term, and E_{Global} represents the flow field that tends to change smoothly. It means optimizing the global energy.

Based on logarithmic operation, the covariance matrix is mapped from nonlinear space to linear space. Secondly, the use of support vector machine allows to classify the descriptors by using mathematical tools and coding them. After the matrix logarithm operation is projected into the vector space, a nonpositive definite symmetric matrix is obtained. After obtaining the covariance matrix, the logarithm of these covariance matrices is calculated as shown in Equation 10:

$$\begin{cases} Cov = p_1 \cdot \lambda \cdot p_2 \\ \log Cov = p_1 \cdot \left(\log \lambda\right) \cdot p_2 \end{cases} \tag{10}$$

After singular value decomposition of covariance matrix, two matrices p_1, p_2 and diagonal matrix λ based on them can be obtained. $\log Cov$ is a symmetric matrix, but, usually, the result is a nonpositive definite. Through the above steps, the symmetric matrix $\log Cov$ can be obtained.

RESULTS AND ANALYSIS

Analysis of Experimental Results

In this study, the authors adopted the quasi-experimental design, because they carried out this research design under natural conditions, without affecting students' class and ignorance of specific experiments, so it has good reliability and validity. This method is often used in educational research. The researchers randomly selected 100 students from five middle schools that offered sports dance courses. Then, they randomly selected 100 students from five middle schools that had never offered sports dance courses. The researchers matched the age, gender, body mass index, and baseline mental health status of students to ensure comparability between the two groups at the beginning of the experiment. The sports dance training lasted for one semester, about four months, three times a week, one hour each time. The specific exercises included three parts: Modern dance, ethnic dance, and street dance. Each dance type included basic step training, skill enhancement, and dance choreography. In addition, there was a 15-minute warm-up time before the start of each class, including stretching and basic physical training, to prevent injuries and improve students' physical fitness. The authors used self-assessment questionnaires to evaluate students' emotional state and social skills, and used physical tests (e.g., push-ups and sit ups) to assess changes in their physical fitness. They conducted these evaluations before training (baseline), during training (two months), and after training (four months). After the test, the students majoring in psychology and authors completed the data input together, and carefully checked the data to ensure the accuracy of the data input.

As Table 1 shows that the total average score and the number of positive events of the two groups have very high significant differences, and the mental health level of the students in the experimental group is obviously higher than that of the students in the control group, which indicates that sports dance training greatly improved the mental health level of college students.

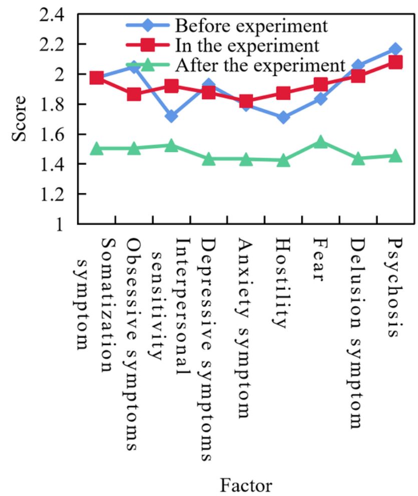
Sports dance can bring spiritual happiness and spiritual relaxation to students. Students can choose music and dance at will according to their own psychology, and cultivate their psychological stress resistance in light or passionate music. Therefore, sports dance provides a way to relieve emotions.

Figure 3 intuitively shows the scores of all dimensions of mental health in the experimental group after a 10-week experimental teaching process. There are significant differences between somatization symptoms in the middle of the experiment and those before the experiment ($P<0.\ 01$), obsessive-compulsive disorder ($P<0.\ 05$), and other factors have no significant differences. As the

Table 1. Comparison of Total Average Score and Positive Items Between the Two Groups

	Experimental group		Control group		P
	Mean	Standard deviation	Mean	Standard deviation	
Total average score	1.55	0.52	2.41	0.24	<0.01
Number of positive items	20.14	15.36	26.87	14.16	<0.01

Figure 3. Changes of Mental Health Level in the Experimental Group Before and After the Experiment



teaching content of public physical education, dance can effectively improve the mental health level of college students.

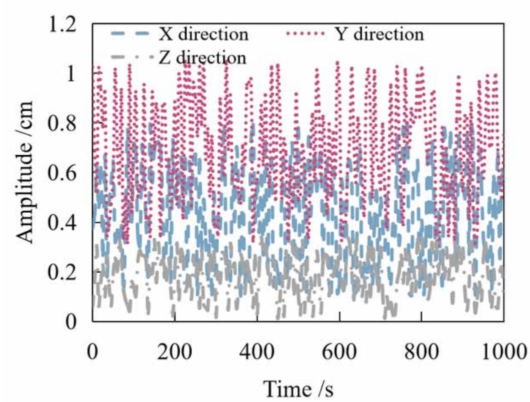
Table 2 is a comparative statistical table of physical fitness indexes of exercisers before and after the experiment. It evidences that the sit-ups and the flexion of the sitting body are all improved one minute after the experiment, with $P < 0.05$, showing significant changes. The standing jump has also increased, but the change is not obvious, its $P > 0.05$, and there is no significant change. After the experiment, the number of sit-ups that participants can complete within one minute increased. This indicates an improvement in the abdominal muscle endurance and core strength of the participants. The significance level ($P<0.05$) is a threshold used in statistics to determine whether a result is statistically significant. In this experiment, $P<0.05$ means that the improvement in sit-ups and sit forward flexion by the exerciser before and after the experiment is unlikely to occur by chance. In other words, sufficient evidence suggests that the experiment had a positive impact on the physical fitness indicators of participants, particularly abdominal muscle endurance, core strength, and lower back and leg flexibility. For the results of standing jump, $P>0.05$ indicates that the improvement in standing jump did not reach a statistically significant level. In other words, the increase in standing jumps after the experiment may be caused by random variation, rather than a direct result of experimental intervention.

The flexion of the sitting body is an important indicator of flexibility. Flexibility is also one of the important manifestations of physical fitness. Compared with before the experiment, after the

Table 2. Comparative Statistics of Physical Fitness Indexes of Exercisers Before and After the Experiment

Index	Group	Mean	Standard deviation	P
One-minute sit-ups	Before the experiment	30.128	1.433	0.045
	After the experiment	39.638	1.668	
Sit and reach	Before the experiment	11.242	3.401	0.036
	After the experiment	16.038	4.012	
Standing long jump	Before the experiment	177.526	4.558	0.122
	After the experiment	179.361	5.214	

Figure 4. Error Result of Shoulder Joint Position Estimation



experiment, the performance of sitting body flexion was significantly improved. The main reason is that many postures of sports dance will have the twisting and stretching of waist and abdomen, and the stretching of leg muscles, especially the back side of legs and the inner side of thighs. From this point of view, the exercise of sports dance can increase the range of motion between joints, so the front flexion of sitting position is significantly improved.

In this study, the authors used the inertial measurement unit integrated with triaxial accelerometer, triaxial gyroscope, and triaxial magnetometer for the corresponding test, and the sampling frequency was 100 Hz. The position and direction relationship of the frame-to-frame coordinate system is obtained by torsion and exponential mapping. Figure 4 shows the position estimation error of shoulder joint.

Generally speaking, the estimation error of shoulder joint is low, because in this study the authors adopted the chain model of sports mechanics, so the error of the parent node will accumulate to the child node.

In this section, the authors added random pollution to the test data set to evaluate the robustness of the proposed regression method to partial occlusion in multiposes. For each face picture in the original test set, they randomly selected one of different parts (e.g., eyes, nose, and lips) and blocked the part with the same size in the background. Figure 5 depicts the cumulative error distribution curve on the pollution test set.

The results show that, after partial occlusion, the positioning accuracy of all methods decreases as a whole, especially the performance of the traditional cascade regression method, while the robust regression method can still maintain high accuracy. Compared with the current robust regression method and cascade regression method, the authors' method has higher positioning accuracy on the pollution test set. In this study, more than 75% of the sample errors were within 0.1, and the best result compared with the robust method RNN was 68%. This indicates that the authors' proposed method can ensure that the error between most predicted positions and the actual position is very small when performing positioning tasks, specifically within the error range of 0.1. This data point is very important because the percentage of sample error within the 0.1 range is an intuitive indicator of positioning accuracy. A high percentage means that the model performs better in localization tasks and can produce prediction results that are closer to the true values. In the case of partial occlusion, the overall positioning accuracy of all methods decreases, but the authors' method can maintain high accuracy, indicating that the model has good robustness to changes in input data (e.g., occlusion). This is crucial for complex environments commonly found in practical application scenarios.

Figure 6 shows the experimental results of the comparison between this method and the benchmark method in different dance combinations of data sets. In the recognition of different dance combinations, the recognition rate of this method is higher than that of the benchmark method, as a whole.

Figure 5. Cumulative Error Distribution Curve on Test Set

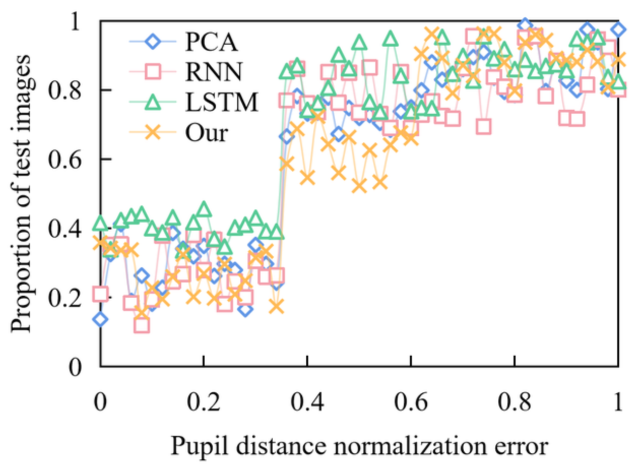
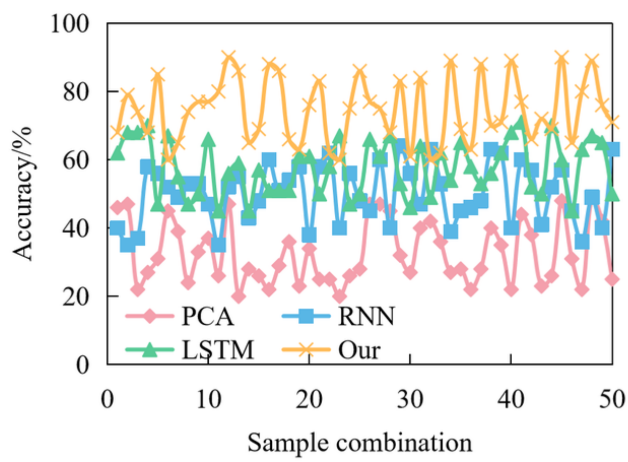


Figure 6. Comparison of Experimental Results

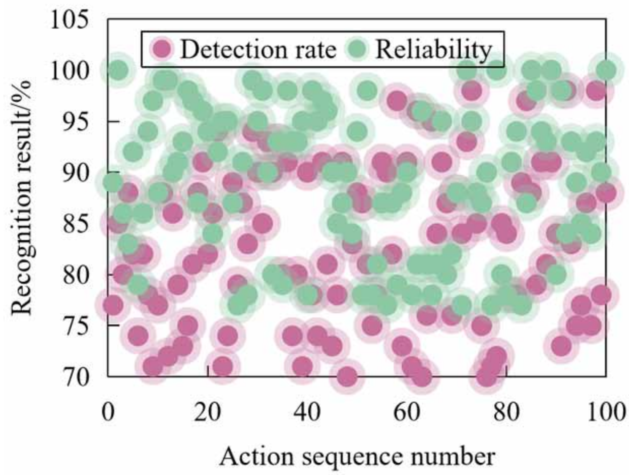


It also shows that the benchmark method based on track feature fusion cannot accurately represent dance movements when the dance movements are too complicated, similar movements, and self-occlusion. The fusion method the authors proposed in this paper can avoid the above effects, to some extent, thus improving the recognition rate of dance, so it also verifies the effectiveness of this algorithm.

Figure 7 shows the detailed recognition results of various action patterns when the authors' method recognizes the action data stream. It evidences that recognition errors are mainly caused by substitution errors, because there are similarities between actions of the same kind, so they are easily confused with each other.

Because there are transition frames between the two action modes in the input data stream, and these transition frames are similar to their front and back action modes, some frames of them with the front and back modes are easily mistaken for legal action modes, which leads to insertion errors.

Figure 7. Identification Results of Various Actions



Compared with other methods, the method based on key table can not only achieve higher detection rate and reliability, but also achieve faster recognition speed.

Analysis of Practical Applications

In exploring the research field of the impact of sports dance on the physical and mental health and comprehensive quality of college students, the authors gained a deep understanding of the potential benefits brought by this unique sports activity. Sports dance, as an activity that combines sports competition and dance art, not only enriches the extracurricular life of college students, but also plays a positive role in improving their physical and mental health and social adaptability. However, just like any scientific research, the authors' exploration inevitably faces a series of limitations. These limitations not only affect the interpretation of their research results, but also pose challenges and opportunities for future research directions, as follows:

1. **Sample Scope and Representativeness:** The study may be limited to specific regions, universities or a small group of college students, which may affect the universal applicability and generalizability of the research results. The selection and scope of samples have a significant impact on the universality of research conclusions. In future research, the universality of research results can be improved by increasing sample size and ensuring sample diversity (e.g., incorporating college students from different regions, types of universities, and cultural backgrounds as research subjects).
2. **Limitations of Research Methods:** In this study, the authors adopted template-based recognition methods and VR technology to explore the effectiveness of sports dance teaching. Although these methods are advanced, they also have limitations. For example, template-based recognition methods may not be able to fully capture all the subtle differences in dance movements, and the application effect of VR technology may be affected by differences in technical equipment and personal experience. Future research should optimize research methods, and explore and adopt more metaresearch methods, such as a hybrid approach combining qualitative and quantitative research, to obtain more comprehensive insights. For research based on VR technology, researchers should consider using more advanced technologies and devices, as well as developing more precise motion capture algorithms, in order to improve recognition accuracy and user experience.

3. **Time Span and Long-Term Effects:** Research may focus on the short-term effects of sports dance teaching, with insufficient examination of its long-term impact on the physical and mental health and comprehensive quality of college students. Long-term tracking studies can provide a more comprehensive assessment of the lasting effects of sports dance on individuals.
4. **Multidimensional Assessment of Mental Health:** Although the authors aimed to explore the impact of sports dance on the mental health of college students, mental health is a complex multidimensional concept that involves multiple aspects, such as emotions, cognition, and social adaptation. This study did not fully cover all dimensions of mental health. In the future, the authors will consider conducting long-term tracking studies, designing and implementing long-term research projects to observe and evaluate the persistence of the impact of sports dance on the physical and mental health and overall quality of college students.

The research on the impact of sports dance on the physical and mental health and comprehensive quality of college students the authors discussed in this paper has practical application value in various fields, especially in education, health promotion, and social development. Some specific real-life application scenarios are:

1. **Reform of Physical Education in Universities:** The research results can provide a basis for the reform of the content of physical education courses in universities, encourage schools to incorporate sports dance into public physical education courses, enrich students' choices of sports activities, promote their physical and mental health and personality development, and provide targeted teaching methods and technical support, such as using VR technology to enhance the interactivity and fun of dance learning.
2. **Psychological Health Promotion Program:** Based on research findings, universities and communities can design and implement psychological health promotion programs with sports dance as the core, helping to alleviate students' psychological stress, improve emotional status, and enhance social skills. This can include organizing workshops, lectures, and club activities related to sports dance to provide opportunities for students to learn and participate, while enhancing communication and teamwork among students.
3. **High Quality Talent Cultivation:** Taking sports dance as one of the ways to enhance students' comprehensive quality, by cultivating their artistic aesthetics, physical coordination ability, and expression ability allows to cultivate high-quality talents with innovative spirit and good physical and mental health for society. The promotion and application of sports dance can help improve students' confidence and self-efficacy, laying a solid foundation for their future career and social life.
4. **The Richness of Social and Cultural Activities:** Sports dance, as an activity that integrates sports competition and dance art, can be an important component of social and cultural activities, enriching community cultural life, promoting cultural diversity and artistic innovation. Organizing sports dance performances, competitions, and exchange activities can not only enhance public awareness and interest in sports dance, but also stimulate society's attention to physical health and art education.

Through these practical applications, this study can not only promote the popularization and development of sports dance in universities and society, but also bring positive impacts to individuals and society, including improving the physical and mental health level of college students, promoting the cultivation of high-quality talents, and enriching social and cultural activities. This study on the impact of sports dance on the physical and mental health and comprehensive quality of college students has opened up a beneficial exploration field, but future research can be further deepened and expanded in multiple directions:

1. **Technology Integration and Innovation:** Combining modern technologies such as VR, augmented reality, and AI, can develop more interactive and fun sports dance teaching tools and platforms. This not only enhances the learning experience, but also optimizes training effectiveness through data analysis, providing support for personalized learning.
2. **Systematic Research and Evaluation Model:** It is importan to build a comprehensive evaluation system that not only focuses on the impact of sports dance on physical health, but also includes multidimensional evaluations such as mental health, social adaptability, and teamwork ability. Long-term tracking and systematic evaluation allows to gain a deeper understanding of the role and mechanism of sports dance in the growth process of college students.
3. **Interdisciplinary Research and Cooperation:** It is key to promote the interdisciplinary integration of sports science, psychology, education, sociology, and other fields, and explore the impact of sports dance on college students from multiple perspectives and levels. Besides, interdisciplinary collaboration enriches research perspectives and enhances the depth and breadth of research.

Through the exploration of these future development directions, the research field involved in this paper is expected to achieve deeper development in both theory and practice, providing richer and more effective sports dance education and health promotion services for college students, and also providing new ideas and methods for research in related fields.

CONCLUSION

Sports dance has potential positive effects on improving individual physical and mental health and overall quality, but research on its impact on the mental health of college students is limited, especially lacking scientific research to explore the actual impact of sports dance on promoting the mental health of college students. In view of this, in this study the authors aimed to explore the impact of introducing sports dance into public physical education classes in universities on the physical and mental health and comprehensive quality of college students. This study delved into the impact of sports dance on the physical and mental health and overall quality of college students in public physical education courses, and examined the potential application of VR technology in dance education. The authors adopted a template-based recognition method to extract key frames of motion sequences, and matched the extracted motion feature data with standard motion data in the database to achieve recognition of the motion to be recognized. The results indicated that sports dance, as an activity that combines sports and art, has a significant positive effect on enhancing the physical self-esteem, reducing psychological pressure and improving emotional state of college students. This indicates that sports dance can not only enrich the physical activities of college students, but also effectively promote their mental health. By using template-based recognition methods to capture and recognize dance movements, this study demonstrated the enormous potential of VR technology in improving the efficiency and quality of dance teaching. VR technology can provide a more intuitive and interactive learning experience, helping students better understand and master dance movements, indicating the future development trend of dance education. This study demonstrated the application value of VR technology in dance education, providing new perspectives and possibilities for traditional dance teaching methods. In the future, with the further development of technology and the continuous updating of educational concepts, the teaching mode of combining sports dance with VR technology is expected to play a greater role in university physical education, providing strong support for cultivating healthy and comprehensively developing high-quality talents. However, the template-based recognition method in this study may not be able to fully capture all the subtle differences in dance movements, and the application effect of VR technology may be affected by differences in technical equipment and personal experience. In the future, the authors plan to use more advanced technologies and devices, as well as develop more precise motion capture algorithms, in order to improve recognition accuracy and user experience.

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DATA AVAILABILITY

The Figures and Tables the authors used to support the findings of this study are included in the paper.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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