

Development Of A Biomechanical Analysis Prototype For Sports Dance Pedagogy Using Wearable Devices And Mobile Terminals

Pengjie Zhang, Hui Ma, Shaobin Zhang, and Yan Wang*

Hebei Agricultural University, Baoding 071000, China

* Corresponding author. E-mail: tgbwangyan@hebau.edu.cn

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With the increasing demand for precision and personalization in physical education, biomechanics has emerged as a pivotal discipline in enhancing the quality of sports dance instruction. This study investigates the integration of biomechanical analysis and intelligent mobile terminals into sports dance pedagogy. It first proposes a system architecture that leverages wearable devices and multimedia teaching terminals to enable real-time feedback, kinematic analysis, and personalized instructional support. Based on national curriculum standards and pedagogical theory, a hierarchical indicator system comprising 3 primary, 10 secondary, and 32 tertiary teaching strategy indicators was constructed and validated using expert consultation and Kendall's concordance test ($W > 0.75$). A weighting system was then applied to rank the importance of each indicator. A case study involving 25 physical dance instructors across six universities was conducted to evaluate current teaching practices and assess the applicability of the proposed strategy framework. Results indicate that most instructors rely heavily on traditional methods such as demonstration and verbal instruction, with limited use of multimedia or theoretical integration.

Keywords: biomechanics; sports dance; wearable devices; intelligent mobile terminals; motion analysis

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1. Introduction

In recent years, the field of sports education has witnessed a profound shift toward data-driven and precision-based instruction, with biomechanics emerging as a cornerstone of this transformation. Biomechanics, which systematically studies human motion through the lens of mechanical principles, provides a scientific basis for analyzing movement patterns, [1, 2] optimizing performance, and minimizing injury risk. This capability is particularly significant in disciplines like sports dance, where athletes must precisely coordinate posture, rhythm, balance, and muscle force distribution. Unlike traditional sports, sports dance straddles the boundary between athletic performance and artistic expression, placing exceptional demands on both aesthetic accuracy and technical precision.

Traditionally, sports dance education has largely relied on visual demonstration and teacher-student imitation, wherein instructors perform movements for students to mimic. While such methods may foster intuitive understanding, they inherently lack objectivity, repeatability, and real-time corrective mechanisms. Teachers must rely heavily on personal experience and observation, which may lead to inconsistencies in instruction. Furthermore, [3, 4] students often struggle to internalize the biomechanical principles underlying complex movements due to the absence of immediate and quantifiable feedback. These challenges hinder not only the efficiency of technical acquisition but also the depth of understanding and individualization of instruction.

The growing availability of wearable sensors, intelligent mobile terminals, and motion capture technologies

has opened new avenues for integrating biomechanics into physical education. These tools can collect real-time data on parameters such as joint angles, angular velocity, ground reaction force, and center of mass trajectory, transforming qualitative instruction into a measurable and adaptive process. When paired with intelligent teaching systems, such devices can facilitate interactive feedback, autonomous learning, and scientific evaluation of motor skills. [5, 6] For instance, smart mobile terminals can record student performances, analyze them via embedded algorithms, and provide targeted suggestions to enhance movement precision and safety.

Despite the promise of these technologies, current biomechanical teaching systems often suffer from limited flexibility, poor integration across teaching stages, and insufficient support for dynamic classroom environments. Many platforms operate under laboratory conditions or require specialized technical personnel to manage data acquisition and analysis. This lack of practicality impedes widespread classroom adoption. Moreover, few studies systematically evaluate the pedagogical impact of biomechanical tools in a real-world educational context, particularly in sports dance instruction where artistic and technical dimensions must be harmonized.

To address these limitations, this study proposes an integrated sports dance teaching system that combines biomechanics-based feedback with intelligent mobile terminal applications. The system comprises four key modules: a multimedia teaching resource library, a mobile terminal-based real-time feedback platform, motion data acquisition devices (e.g., cameras and wearable sensors), and a centralized resource management server. By leveraging these components, the system supports high-frequency feedback loops between teachers and students, [7–9] enables visual correction of movement deviations, and fosters deeper engagement with biomechanical principles. Teachers can demonstrate, record, and playback student movements while providing in-the-moment guidance projected onto large classroom displays. Students, in turn, can access personalized feedback and participate in discussions before and after class.

This paper further establishes a scientifically grounded evaluation framework for teaching strategies by employing expert surveys, indicator construction, and consistency validation through Kendall's harmony coefficients. The comprehensive analysis revealed key weaknesses in current teaching approaches, such as over-reliance on teacher demonstration, underutilization of theoretical support, and limited student-centered practice strategies. In response, the proposed system introduces a structured, quantifiable,

and adaptive instructional paradigm that promotes technical mastery, theoretical understanding, and injury prevention.

2. Materials and methods

Through an investigation and analysis of the teaching processes in certain physical education courses and student classes, it was observed that the predominant approach to physical education dance instruction relies on teacher demonstrations. In this traditional format, students primarily observe the teacher's movements during class and subsequently attempt to imitate them under the teacher's guidance. The incorporation of modern educational technology is limited, [10–12] typically involving teachers playing instructional videos during class. This method often requires additional teaching support personnel to operate equipment, increasing the complexity of class organization.

Students are generally limited to observing their movements in mirrors during practice. While this approach works for some sports movements, it proves ineffective for others where selfobservation is impractical. Furthermore, using mirrors can divert students' attention, hampering their focus during practice. Interviews with instructors revealed additional challenges. Many teachers reported the inability to use blackboards during physical dance instruction and highlighted the difficulties of integrating theoretical teaching conducted in classrooms with the practical nature of dance courses.

The introduction of intelligent mobile terminals has significantly enhanced the compatibility of teaching processes and resources. These tools expand class content and foster improved communication between teachers and students, as well as among students, [13, 14] both before and after class. Such integration demonstrates potential for creating a more interactive and cohesive learning environment for physical education dance courses.

2.1. System structure design

The overall architecture design of the teaching system for the needs of teachers and students in the process of teaching physical dance is shown in Fig. 1.

Teaching resource library: It is mainly used to store high-quality teaching resources used by teachers in the course of lesson preparation. Teachers can store their multimedia courseware and videos according to their lesson planning, and also provide help for students to pre-study and review in class. In addition, a discussion forum is deployed in the learning resource server to facilitate student-student and student-teacher communication. The proposed system integrates wearable sensors, wireless communication,

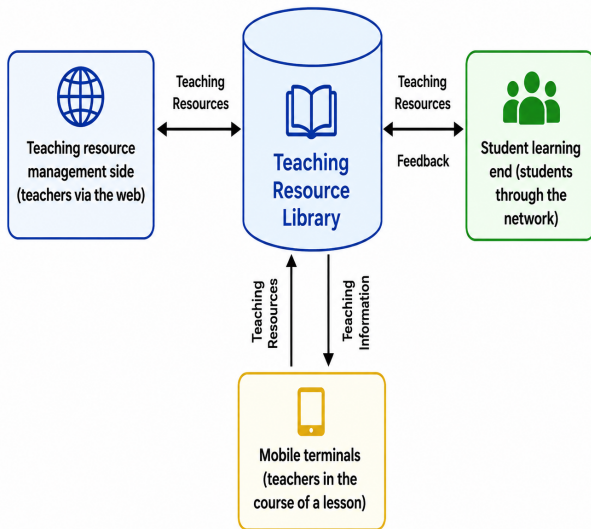


Fig. 1. Overall architecture design.

intelligent mobile terminals, and cloud/server modules to collect, process, store, and visualize biomechanical motion data in real time. This coordinated workflow provides immediate instructional feedback, supports accurate movement analysis and personalized technique correction, and enhances instructional efficiency and sports dance learning through seamless data transmission and centralized resource management. The teaching resource management terminal enables teachers to upload, download, and manage multimedia teaching resources through web browsers, computers, and wireless mobile terminals regardless of location. Integrated cloud-based storage and synchronization provide secure access to instructional materials, movement records, and personalized feedback across multiple devices, supporting continuous, flexible, and personalized sports dance learning.

Mobile terminal: mainly used for teachers in the process of class, teachers can access the teaching resources in the server through the mobile terminal in the process of class, if not in the wireless network coverage of the venue, teachers can also download the content of the class to the mobile terminal in advance, convenient for use in class. The teacher can also connect the mobile terminal to the multimedia projector in the course of the lesson to realize the same screen of the mobile terminal and the projection, which can easily combine the course and multimedia technology to realize the writing of the teacher's board in the process of teaching physical dance. Teachers can also take videos and photos of students' movements in the teaching process and play them on the big screen, and make timely corrections to students' technical movements, which

can greatly improve the efficiency of the classroom and increase students' motivation in class. The teacher can also upload the files and videos of the class process to the server [15]. The effectiveness of the proposed system depends on adequate lighting, practice space, stable wireless connectivity, and multimedia equipment, which ensure reliable sensor communication, accurate motion capture, and uninterrupted real-time feedback. The teaching resource library supports resource classification, storage, indexing, updating, and personalized recommendations, while the resource management terminal and discussion forum facilitate multimedia resource management, teacher-student interaction, peer collaboration, and personalized learning. Student side: Mainly provides students with pre-study and review before and after class, as well as discussion of learning content in the discussion forum.

2.2. Intelligent mobile terminal application design

According to the analysis, the teaching system for mobile terminals within the need to carry out local area network environment to work, for this part of the structure design as shown in Fig. 2.

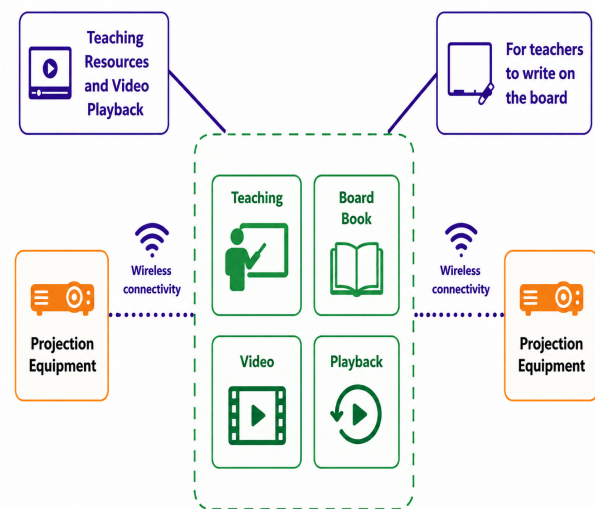


Fig. 2. Intelligent mobile terminal application structure design.

The mobile terminal and projection system support real-time teacher-student interaction by enabling immediate movement correction and personalized feedback. Wearable sensors collect biomechanical parameters, including joint angles, angular velocity, acceleration, and centre of mass trajectory, while synchronized communication among wearable devices, mobile terminals, wireless networks, and projection equipment ensures accurate motion analysis, seamless data transmission, and effective sports dance in-

struction. The system integrates motion analysis software with wearable sensors to acquire biomechanical parameters, including joint angles, angular velocity, posture alignment, movement trajectory, balance indices, acceleration, and centre of mass, for objective evaluation of movement quality and technical execution. Sensors are securely positioned, synchronized, and calibrated before each session, while standardized data acquisition and real-time kinematic analysis provide personalized instructional feedback, enabling accurate movement correction, performance monitoring, and continuous improvement in sports dance techniques. The system enhances student engagement by allowing learners to visualize their movements, while wearable sensors collect motion signals that are processed into quantitative biomechanical parameters. Real-time kinematic analysis compares these measurements with reference movement patterns and provides personalized instructional feedback, enabling instructors to guide movement correction and helping students refine sports dance techniques while improving their understanding of biomechanical principles.

Moreover, the system supports remote learning by allowing students to access recorded lessons and feedback outside of class hours through mobile devices, enhancing learning flexibility and reinforcing concepts taught in class. This combination of real-time feedback, motion analysis, and accessible learning resources helps create a more holistic and effective learning environment for dance students. Before data collection, wearable sensors were initialized, synchronized, and calibrated to ensure reliable, repeatable, and accurate biomechanical measurements, while secure sensor placement and signal filtering minimized errors caused by sensor displacement, environmental interference, transmission delays, and motion artifacts. Motion capture data were synchronized with video recordings and analyzed in real time to identify movement deviations, generate automated biomechanical feedback, and enable teachers to provide immediate corrective guidance, thereby improving movement quality and sports dance performance.

2.3. Interactive teaching in physical dance classroom

The interactive teaching mode of students learning physical education based on mobile intelligent terminal devices is shown in Fig. 3.

The system records students' movement videos together with biomechanical analysis results, enabling performance comparison, self-assessment, and identification of movement deficiencies and posture deviations. Combined with collaborative practice, peer discussion, formative assessment, real-time feedback, and continuous teacher-student

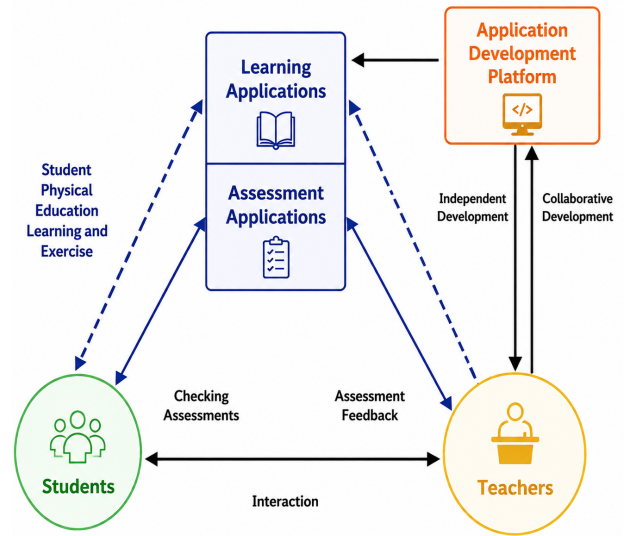


Fig. 3. Interactive learning model of physical education based on mobile terminals.

interaction, the interactive learning model promotes reflective learning, continuous skill refinement, learning autonomy, and improved sports dance performance.

2.4. Construction of physical education dance teaching strategy indicators

After collating the literature and books related to physical education teaching strategies, the structure indexes of physical dance teaching strategies were initially constructed based on the National Curriculum Plan for Physical Education Undergraduate Programs in General Higher Education Schools and the Theory of Physical Education Teaching. After the indicator questionnaires were collected, the mean value of each item was calculated based on the score assigned to each indicator by the experts, and the results are shown in Table 1 and Table 2.

Based on the results from the table above, the initial physical dance teaching strategy indicators were revised. Indicators with a mean value lower than 3.5 were eliminated. For example, the mean value of the B1 diversified introduction strategy index was 3.15, the B6 cooperative communication strategy index was 3.40, and the B7 thinking guidance strategy index was 3.30, so these three indicators were removed. Following expert recommendations, the secondary index B6 (cooperative communication strategy) was integrated into B4 (practice strategy), with the aim of achieving effective group practice through communication and collaboration. Similarly, the B7 thinking guidance strategy was merged into B3 (explanation strategy), as the objective of providing guidance can be accomplished

Table 1. Mean values of the first- and second-tier indicators in the first round of expert survey.

Primary Indicators	Average value	Secondary Indicators	Average value
A Instructional preparation strategies	4.50	A1 Analysis of students' learning situation strategy	4.40
		A2 Selecting teaching content strategies	4.30
		B1 Diversified introduction strategies	3.10
B Instructional implementation strategies	5	B2 Presentation strategy	4.35
		B3 Explanation strategy	4.90
		B4 Practice strategy	4.50
		B5 Instruction strategy	4.15
		B6 Thinking guidance strategy	3.50
		B7 Cooperation and communication strategy	3.40
C Instructional evaluation strategy	4.40	C1 Differentiation of evaluation criteria strategy	4.20
		C2 Evaluation content comprehensiveness strategy	4.85
		C3 Diversification of evaluation subjects	3.75
		C4 Diversification of evaluation methods	3.85

more effectively through clear explanations[16]. Indicator weights were determined by aggregating expert evaluation scores, applying normalization to obtain relative weights, and ranking the indicators according to their normalized values. The hierarchical indicator system was developed through a literature review, curriculum guidelines, and pedagogical theories, refined through two rounds of expert consultation, and statistically validated using Kendall's concordance analysis to confirm expert agreement and the reliability of the finalized framework.

In the second round of expert surveys, the same index screening method was applied as in the first round. Indicators that received objections were revised according to the feedback provided by the experts. After distributing the revised indicators to 20 experts, no significant changes were made, indicating that the experts recognized and approved the revised indicators, meeting the study's criteria. To assess the consistency and objectivity of the experts' ratings, the Kendall's concordance coefficient formula was employed. The formula used for this test is as follows:

$$W = \frac{\sum R_i^2 - \frac{(\sum R_i)^2}{N}}{\frac{1}{12} K^2 (N^3 - N) - K \sum \frac{3-n}{12}} \quad (1)$$

$$W = \sum_i^n \frac{(R_i - m(n+1)/2)^2}{(m^2) - n(n^2 - 1)/12} \quad (2)$$

The primary, secondary, and tertiary indicators achieved Kendall's W values of 0.892, 0.847, and 0.803, respectively, with all associated χ^2 tests being statistically significant ($p < 0.001$). Since all W values exceeded 0.80, the results indicate a high level of agreement. These findings demonstrate that the indicator framework possesses strong expert consensus and provides a dependable foundation for subsequent weighting and evaluation procedures.

First, the ratings provided by the experts for each indicator were aggregated by calculating the arithmetic mean of

all expert scores. The aggregated score for the i th indicator was computed as

$$S_i = \frac{1}{n} \sum_{j=1}^n x_{ij} \quad (3)$$

where x_{ij} denotes the score assigned by the j th expert to the i th indicator, and n is the total number of experts.

Comparability among indicators measured on the same five-point Likert scale, the aggregated scores were normalized using the sum normalization approach. The normalized weight of each indicator was calculated as

$$W_i = \frac{S_i}{\sum_{i=1}^m S_i} \quad (4)$$

where m represents the total number of indicators at the corresponding hierarchical level. The normalization procedure ensured that the sum of all indicator weights equaled one, enabling consistent comparison and ranking across indicator categories. The Delphi panel comprised experts with doctoral or master's qualifications and more than 10 years of experience in sports dance education, biomechanics, and physical education, who evaluated the indicators through two consultation rounds, with revisions based on expert consensus, mean scores, and qualitative recommendations to ensure a reliable and authoritative framework.

3. Results and discussion

In this study, 25 physical dance teachers who taught physical dance special classes in six colleges and universities in a Province were surveyed respectively, and the findings were as follows.

3.1. Results and analysis of teaching preparation strategies of physical dance

Teaching preparation strategy is the premise of teachers' teaching activities, including the strategy of analyzing stu-

Table 2. Mean values of indicators at three levels in the first round of expert survey.

Tertiary indicators	Average value
A11 Technical skill level	4.80
A12 Theoretical knowledge base	4.50
A21 Sorting out the structure of physical education materials	4.35
A22 Integrate the content of other subjects	4.15
A23 Orchestrating the overall knowledge framework	3.70
B11 Question-based introduction	4.85
B12 Project-based introduction	4.35
B13 Music-based introduction	4.65
B21 Visualization with pictures	3.65
B22 Processing with video	4.25
B23 Detailed teacher demonstration	5
B24 Student presentation competition	4.15
B31 "Story" approach to introduction	3.95
B32 Teaching of specialized terms	5
B33 Comprehensive knowledge support	4.45
B34 Inspiring questions for guidance	4.55
B35 Motivational language encouragement	3.85
B41 Targeted practice content	4.85
B42 Flexible practice format	4.35
B43 Practice in a gradual manner	3.75
B44 Reasonable control of practice load	4.15
B51 One-on-one guidance	4.55
B52 Group-based instruction	4.65
B53 Group instruction for error correction	3.75
B54 Theory prompting instruction	3.85
B61 Guiding students' thinking on the integration of multidisciplinary knowledge	4.25
B62 Inspiring students to apply theoretical knowledge to solve technical problems	4.45
B63 Encourage students to think independently and try to innovate	4.30
B71 Discuss with each other in small groups	4.30
B72 Discuss with each other and the teacher	4.30
C11 Gender differences between men and women	4.30
C12 Differences in learning ability	4.75
C21 Degree of understanding of theoretical knowledge	4.30
C22 Degree of technical skill mastery	4.75
C31 Teacher evaluation	4.65
C32 Self-evaluation	4.35
C33 Intra-group mutual evaluation	4.15
C34 Inter-group evaluation	4.35
C41 Process evaluation	1.25
C42 Summative evaluation	4.25

dents' learning situation and the strategy of selecting teaching contents.

This shows that most physical dance teachers pay too much attention to the teaching content of physical dance

itself when they select the teaching content before class, and less to the content of other subjects.

3.2. Results and analysis of strategies implemented in physical education dance

The strategies implemented in class reflect the teachers' teaching ability and effectiveness, and are the main manifestation of teachers' teaching level and the key link of students' learning.

The strategies implemented in class include: Presentation strategies, explanation strategies, practice strategies, and instruction strategies.

According to the results shown in Table 3 and Fig. 4, 60% of physical dance teachers frequently use teacher demonstrations to illustrate the details of movements to students, while 40% rarely use visual aids, such as pictures, to present the teaching content. Additionally, 40% of the teachers never have students perform demonstrations themselves, and 11 out of the 25 teachers surveyed (44%) never allow students to view physical dance videos.

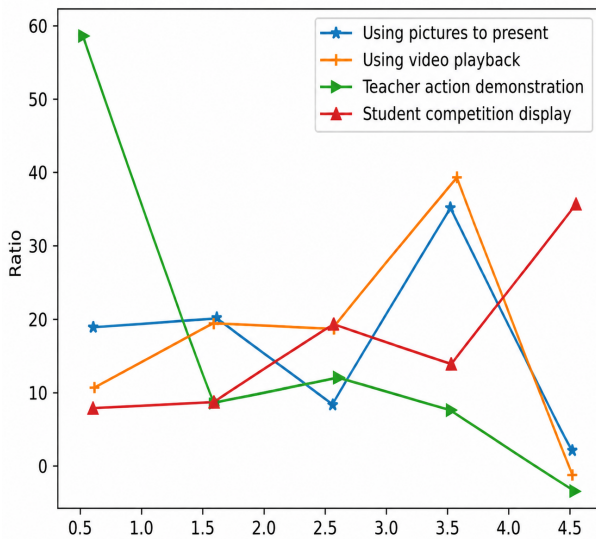
From the analysis of these data, it can be concluded that physical dance teachers primarily rely on a single method of instruction, mainly through their own demonstrations. While teacher demonstrations help clarify the flow of technical movements and are essential for students to accurately imitate the movements, relying solely on this method can lead to a decrease in students' long-term interest in learning. To achieve the desired teaching outcomes, it is crucial for teachers to incorporate a variety of presentation strategies and use them in combination, enriching the learning experience and maintaining student engagement.

From the statistics in Table 4 and the results in Fig. 5, it can be concluded that 40% of the physical dance teachers would let students practice step by step until they mastered the exercise content; 32% of the teachers seldom used multiple organizational forms to let students practice the teaching content. The survey findings indicate the importance of integrating diversified presentation strategies, student-centred practice, theoretical knowledge, and personalized instructional methods to enhance learning effectiveness. These observations demonstrate that biomechanics-supported teaching promotes objective movement evaluation, active student participation, and improved technical skill acquisition in sports dance education.

The results of the survey showed that a few teachers would use flexible and varied organizational forms to let students practice, while most teachers still organized students' practice in the traditional single practice way. Because of the rigid organization and weak interest, they can-

Table 3. Survey statistics of teachers' use of presentation strategies (N = 25 unit: Person).

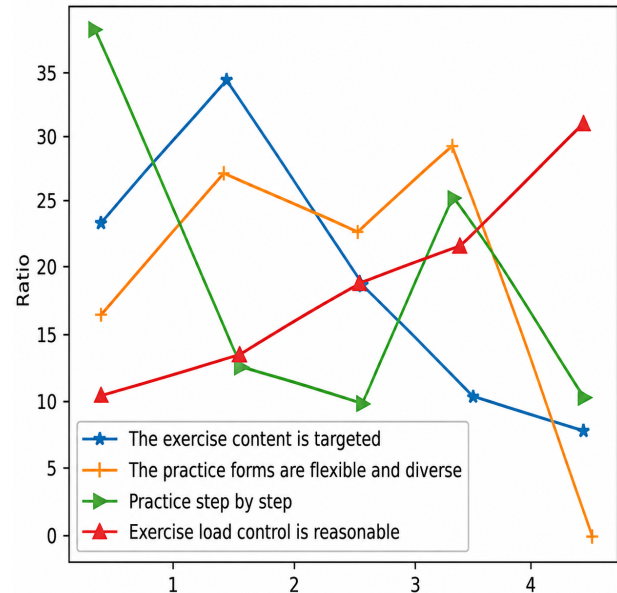
Strategies	Always	Often	Sometim es	Rarely	Never
Using pictures to present	4	6	2	11	2
Use video to show	2	6	5	10	2
Teacher demonstration	14	4	3	4	0
Student competition show	3	2	4	6	10

**Fig. 4.** Statistics of the survey on teachers' use of presentation strategies (N = 25 unit:Person).

not reach the understanding of the teaching content in the whole practice, and there is no good practice atmosphere, so they cannot promote the overall practice effect.

According to the data presented in Table 5, 52% of teachers consistently use group error correction to guide students during practice sessions; 44% frequently employ group instruction during lessons; 36% often provide one-on-one targeted instruction, while 4% of teachers do not offer individual guidance; and 60% of teachers rarely incorporate theoretical knowledge related to technical movements into their instruction. The majority of teachers rely heavily on one-on-one instruction.

An analysis of these findings indicates that most physical dance teachers tend to focus on group-based instruction, with less emphasis placed on individualized attention. The instruction predominantly revolves around technical aspects of the movements, with fewer teachers incorporating theoretical knowledge as a foundation for the learning process. This gap suggests that starting from theoretical concepts could significantly enhance students' understanding of the technical movements. By offering theoretical insights before diving into the practical execution, teachers can provide students with a deeper comprehension of the

**Fig. 5.** Statistics of the survey on teachers' use of exercise strategies (N = 25 unit: Person).

principles behind the movements. This approach could also aid in correcting errors more effectively by linking the technical corrections with a conceptual understanding, thus helping students improve both technically and cognitively. Integrating theoretical knowledge into the instructional process would create a more holistic teaching method, fostering better long-term retention and mastery of physical dance skills.

Exploratory Factor Analysis confirmed the validity of the indicator framework (KMO = 0.891; Bartlett's $\chi^2 = 1846.37, p < 0.001$), with three factors explaining 78.64% of the total variance and a Cronbach's alpha of 0.914 , demonstrating strong construct validity and reliability. The usability evaluation indicated high user satisfaction with ease of use, perceived usefulness, and real-time biomechanical feedback, while continuous biomechanical monitoring enabled the detection of unsafe movement patterns, provided immediate corrective feedback, and supported injury prevention and safer sports dance training.

Table 4. Survey statistics of teachers' use of practice strategies (N = 25 unit: Person).

Strategies	Always	Often	Sometimes	Rarely	Never
Exercise content is targeted	5	8	6	4	2
Exercise form is flexible and diverse	3	8	7	7	0
Exercises in a gradual and progressive manner	9	4	3	6	3
Reasonable control of exercise load	3	2	4	7	9

Table 5. Survey statistics of teachers' use of instructional strategies (N = 25 unit: Person).

Strategies	Always	Often	Sometime s	Rarely	Never
One-to-One	7	8	5	4	1
Grouped	10	8	3	4	0
Collective error correction	12	9	3	1	0
Theoretical knowledge tips	1	4	4	16	0

4. Conclusion

This study comprehensively explored the application of biomechanics and intelligent mobile terminals in sports dance education, from system architecture design to empirical teaching strategy optimization. Through expert surveys and empirical case studies, it was found that traditional sports dance teaching methods exhibit significant limitations in interaction, feedback precision, and theoretical integration. The proposed teaching system introduces a practical framework combining intelligent mobile devices, real-time kinematic analysis, and hierarchical teaching strategy indicators. The empirical data confirm that this integration can provide timely movement correction, enhance theoretical understanding, and increase student engagement. Moreover, the refined teaching strategy framework-validated through expert scoring and statistical agreement-offers a structured, data-driven foundation for future teaching innovations. By shifting from teacher-centered demonstration to a multimodal and biomechanically informed instruction model, both teaching efficiency and learning outcomes are significantly improved. The proposed biomechanics-based teaching framework offers long-term educational benefits through personalized learning and objective performance assessment while remaining scalable across different educational institutions. Although successful implementation requires appropriate infrastructure, wearable devices, and instructor training, the framework can be readily adapted to various physical education and sports training environments. This approach not only supports technical skill acquisition but also cultivates a deeper understanding of motion mechanics, promoting safer and more effective sports dance training environments.

Declarations

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Conflict of interest: The authors declare no conflict of interest.

Data Availability Statement: The data generated and analyzed during the current study are available from the author Yan Wang upon reasonable request but are not yet publicly available due to ongoing research.

Code availability: Not applicable.

Author contributions: Conceptualization, SZ and HM; methodology, XM; software, HM; validation, HM and XM; formal analysis, SZ; investigation, SZ; resources, HM; data curation, XM; writing-original draft preparation, SZ; writing-review and editing, XM; visualization, SZ; supervision, XM; project administration, XM; funding acquisition, HM. All authors have read and agreed to the published version of the manuscript.

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