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Research on Performance Analysis and Auxiliary Decision Making System of Sports Competitions Driven by Deep Learning

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ABSTRACT In today's increasingly scientific, refined, and intelligent development of global competitive sports, precise analysis and scientific decision-making of sports performance have become key factors determining training quality, competitive level, and competition outcomes. Traditional sports performance analysis mainly relies on coaches' experience judgment, manual statistics, post event video review and other methods, which have many limitations such as strong subjectivity, single indicator dimensions, incomplete information extraction, poor real-time performance, difficult quantification, and inability to support dynamic decision-making. Deep learning frameworks offer distinct computational advantages over traditional heuristics, particularly in high-dimensional feature extraction and non-linear spatiotemporal modeling. These capabilities facilitate robust applications in athlete biomechanics, tactical trajectory assessment, and predictive injury diagnostics, moving beyond descriptive statistics toward predictive precision. The multi-source sensing structure can be extended to wearable and radio-frequency motion monitoring in sports biomechanics.

INDEX TERMS deep learning,sports performance analysis,pose estimation,wearable sensing,radio-frequency motion monitoring

I. INTRODUCTION

A. RESEARCH BACKGROUND AND SIGNIFICANCE

CURRENTLY , world competitive sports have entered a new stage of development with technology as the core competitiveness. One of the core symbols of building a sports powerhouse is the scientific training process, intelligent monitoring methods, and data-driven decision-making system. Sports performance is a comprehensive external manifestation of athletes' technical application, physical condition, tactical execution, psychological regulation, and collaborative ability in training and competition. Its objectivity, refinement, and real-time analysis are the basic prerequisites for improving training quality, optimizing competition strategies, preventing sports injuries, and tapping into competitive potential [1-3].

For a long time, in evaluating the technical and tactical processes of competitive athletes, people mainly rely on the visual senses, experience accumulation, and post match memory analysis of coaches and researchers. This often takes time and effort, making it difficult to accurately record the time parameters of movement movements (in milliseconds), dynamic changes in spatial and temporal attack and defense situations, implicit energy metabolism state curve maps, and hidden risks of sports injuries and illnesses. With the continuous increase in competition intensity, the increasing complexity of techniques and tactics, and the increasing number of combinations of techniques and tactics, traditional analysis methods are no longer suitable for the "accurate, real-time, complete, and quantitative analysis" of modern competitive sports [4].

In recent years, deep learning has made significant breakthroughs in computer vision, time series modeling, multimodal information fusion, and reinforcement learning decision-making, thereby promoting the implementation of applications such as video based human pose recognition, non-contact sports biomechanics evaluation, continuous action analysis, tactical trajectory analysis, competitive level prediction, and intelligent risk warning [5]. Deep learning can automatically learn high-dimensional features from heterogeneous data sources such as videos, sensors, physiological signals, trajectories, and tactics, without the need for manual rule making to complete end-to-end analysis and prediction. It can serve as a new tool for intelligent analysis and decision-making of sports performance. China has proposed in documents such as the “14th Five Year Plan for Sports Development” and the “Implementation Opinions on Accelerating the Self Strengthening of Sports Technology” to promote the integration of artificial intelligence, big data, deep learning, and competitive sports, and achieve scientific, intelligent, and personalized training and decision-making [6].

In summary, the research on deep learning based sports competition ability evaluation and decision support technology is a practical need to improve China’s sports technology level, and it is also an inevitable trend to promote the combination of sports engineering and emerging artificial intelligence disciplines [7].

B. CURRENT RESEARCH STATUS ABROAD

Foreign countries started early in the integration of deep learning and competitive sports, and have formed a relatively complete technological chain. In the field of computer vision and pose estimation, models such as CNN, HR-Net, VideoPose3D are used to achieve monocular video 3D human pose reconstruction, which is widely used for quantitative analysis of movements in athletics, gymnastics, diving and other events; In terms of temporal modeling, models such as LSTM, TCN, Transformer, etc. are used for sports performance temporal prediction, physiological load deduction, and fatigue state recognition; In terms of tactical analysis, player trajectory extraction, attack and defense formation analysis, passing network modeling, and automatic identification of tactical types are achieved based on multi-target tracking and graph neural network (GNN); In terms of assisting decision-making, reinforcement learning and game theory are used for on-site tactical recommendation, opponent strategy identification, prediction of game winning and losing probabilities, and resource optimization allocation. Some systems have been used in the Olympic Games NBA, Applied in top tier events such as the English Premier League and the World Cup, it significantly improves training efficiency and competition decision-making level [8].

C. CURRENT RESEARCH STATUS IN CHINA

In recent years, domestic research has developed rapidly, mainly focusing on single point technologies such as action recognition, posture estimation, and physiological data processing, and has achieved certain results in evaluation and classification projects such as gymnastics, diving, and martial arts [9]. However, there are still many limitations: firstly, there is no effective integration of data information from different sources, such as visual, inertial, physiological, tactical, environmental, etc., which have not been standardized and further correlated; Secondly, there is no effective method for describing the state of movement, such as how to quantitatively characterize the quality of athletes’ movements, technical/tactical efficiency, as well as the physical load and degree of danger they undertake; Thirdly, it is rarely used to support real-time or near real time decision making. Most of the existing literature is retrospective analysis, lacking the ability for real-time deduction, dynamic optimization, and closed-loop regulation; The fourth issue is insufficient implementation of engineering, lacking a stable, universal, and cross project standardized system [10].

D. RESEARCH SIGNIFICANCE

1) Theoretical Significance

This article establishes the theoretical basis for a deep learning based sports performance analysis and decision-making assistance system, enriching interdisciplinary theories in sports biomechanics, deep representation learning, multimodal information fusion, intelligent decision-making, and more; Develop a deep learning model matching method suitable for the field of sports, further expanding the application scenarios of deep learning technology in the field of sports; Constructing a modularized system of quantitative evaluation and auxiliary decision-making indicators. While the architecture is unified, the system integrates domainspecific evaluation kernels; for instance, it applies kinematic constraint models for scoring events (e.g., diving) and spatiotemporal trajectory logic for team sports (e.g., soccer), filling the gaps in research while respecting the distinct biomechanical and tactical constraints of different disciplines, filling the gaps in research in the field of sports intelligence analysis, and providing theoretical support for research in sports engineering and artificial intelligence [11].

2) Practical Significance

This study may provide a non-contact, real-time, high-precision, and cost-effective method for evaluating athletic abilities in sports competitions, and promote the improvement of training quality and standardization of technical movements; Establishing a reasonable auxiliary decision support system for personalized training, tactical arrangement and adjustment, competition scheduling, injury prediction and prevention, and recovery treatment of athletes is conducive to reducing the risk of sports injuries and improving the scientific nature of preparation work; Realize the transformation of achievements in projects such as intelligent auxiliary training system, big data analysis system for competitions, and talent selection system, promote the innovative development of competitive sports in China, and help realize the dream of building a strong sports country.

E. RESEARCH CONTENT AND METHODS

1) Research Content

(1) The adaptation mechanism and theoretical basis of deep learning and sports performance analysis;

(2) Preprocessing and deep representation methods for multi-source perception data (visual, inertial, physiological, tactical, environmental);

(3) Five core models based on deep learning: action quality assessment, physical load monitoring, tactical recognition, performance prediction, and injury warning;

(4) Multi dimensional quantitative evaluation system and knowledge reasoning mechanism for competitive performance;

(5) Architecture design, functional modules, and engineering implementation of a full scenario assisted decision-making system;

(6) Multi project empirical verification, effect analysis, and optimization strategies.

2) Research Methods

In this article, literature review, multivariate data collection, machine learning modeling, comparative experi ments, subjective evaluation, objective verification, and data analysis were mainly used to ensure its scientific, rigorous, and effective nature [13].

II. CORE CONCEPTS AND THEORETICAL FOUNDATIONS

A. DEFINITION OF CORE CONCEPTS

1) Performance in Sports Competitions

Competitive performance refers to the technical, physical, tactical, psychological, and teamwork performance of athletes or sports teams during training and competition. Competitive performance is a holistic concept that exhibits different characteristics at different time points and is subject to changes, as well as environmental factors. It can be represented by parameters such as sports form, mechanical characteristics, physiological reactions, tactical performance, injury rate, etc. It is an important basis for evaluating training results, inferring sports performance, and arranging competitions [14].

2) Deep Learning

Deep learning is a type of representation learning method based on multi-layer neural networks, which can automatically extract abstract features from high-dimensional, heterogeneous, and unstructured data, achieving end-to-end recognition, prediction, generation, and decision optimization [15]. In sports scenarios, deep learning is mainly used for visual posture understanding, temporal motion modeling, spatiotemporal tactical reasoning, multimodal information fusion, and auxiliary decision generation. It is the core technology for achieving intelligent analysis of competitive performance [16].

3) Competitive Performance Analysis

Competitive performance analysis is a series of processes that utilize various data information to automatically identify, quantitatively evaluate, discover patterns, and predict trends in athletes' movement quality, technical efficiency, physical condition, tactical behavior, injury risk, and competitive potential. This enables the trans formation from raw movement data to understandable, usable, and executable scientific results, ultimately serving training control and competition command [17].

4) Auxiliary decision-making system

Assisted decision-making is a process based on deep learning competitive performance analysis results, using knowledge reasoning, multi-objective optimization, and intelligent recommendation as the foundation to scientifically recommend, optimize strategies, provide real-time warnings, and provide closed-loop feedback for training plan formulation, technical action correction, tactical plan selection, on-site command adjustment, rehabilitation plan planning, athlete selection, and other aspects. The main value lies in the ability to turn data into decisions, turn analysis into action, and improve the scientific and accurate nature of sports training and competition decisions [18].

B. THEORETICAL BASIS

1) Sports Biomechanics and Kinematics Theory

Biomechanics is the description of various parts of the body based on principles of physics, such as the displacement (angle) and distance (position) of the trunk and limbs, as well as velocity, acceleration, strength, torque, power, etc. These can serve as a prior information and evaluation mechanism for deep learning algorithms, with practical significance in action classification, action judgment, and other aspects, enabling artificial intelligence systems to make reasonable and reliable judgments [19].

2) Deep Learning Representation Learning Theory

Deep learning is a learning process that utilizes multi-layer nonlinear mapping relationships to automatically extract high-level semantic representations from input data. In the field of motion, representation learning can convert information such as videos, skeleton points, temporal sequences, and motion trajectories into attrib utes such as action descriptions, strategy descriptions, states, and danger levels, thereby achieving automated understanding and quantitative evaluation of high-order motion behavior, and serving as a computational method for competitive performance analysis [20].

3) Multimodal Data Fusion Theory

Multimodal fusion is the alignment and fusion of various types of motion data, including visual, inertial, physiological, trajectory, environmental, and opponent data, at the feature and decision levels to improve the robustness of analysis and the accuracy of prediction and decision-making. In the field of competition, multimodal fusion can compensate for the shortcomings of single source data, thereby obtaining more comprehensive, robust, and accurate analysis results of competitive performance.

4) Knowledge Reasoning and Intelligent Decision Theory

Intelligent decision-making is the process of forming actionable suggestions for users based on rule-based reasoning, machine learning prediction, and reinforcement learning trial and error optimization, combined with the above analysis results. For specific application objects in the field of sports, in the decision-making process, it is necessary to consider multiple factors such as improving competition performance, reducing injury risk, controlling physical load, and formulating optimal tactics, and ultimately make reasonable, comprehensive, and feasible auxiliary decisions.

5) Theory of athlete load regulation and injury prevention

The theory of load regulation is the physiological basis for physical fitness monitoring, fatigue assessment, and training plan formulation, and reveals the inherent relationship between load, fatigue, recovery, and injury. Based on deep learning, learning long-term temporal information can establish a load fatigue injury correlation model for risk prediction and personalized training decisions, thereby ensuring the safety and sustainability of athlete training.

III. THE TECHNICAL MECHANISM OF DEEP LEARNING DRIVEN COMPETITIVE PERFORMANCE ANALYSIS

A. MULTI SOURCE DATA PERCEPTION AND PREPROCESSING

Sports data analysis mainly involves visual video data, inertial sensing data, physiological monitoring data, trajectory positioning data, tactical statistical data, environmental data, and opponent data. The raw data contains noise, missing data, asynchrony, and varying scales, which require certain preprocessing before deep learning to achieve a unified data standard. Data preprocessing usually includes processes such as data cleaning, removing outliers, supplementing missing values, spatiotemporal alignment, obtaining pose keypoints, coordinate normalization, frame synchronization, and data augmentation. Preprocess the raw unstructured motion data to obtain standardized, unified, and modelable data as input samples, and use this as a basis for deep feature extraction.

Core Model of Deep Learning for Sports
Convolutional Neural Network (CNN)

CNN excels in extracting spatial features and can be applied to human pose detection, action region localization, action frame classification, and action quality scoring in images and videos. In the field of sports analysis, it is commonly used to extract 2D human keypoints from video frames as the basic features for subsequent 3D pose reconstruction and action understanding, as shown in Table 1.

TABLE 1. Deep Learning Models and Applicable Sports Analysis Tasks

Model Type	Core Capability	Typical Application in Sports
CNN	Spatial feature extraction, pose detection	Action recognition, motion segmentation, key point detection
LSTM / GRU / TCN	Time-series dependency modeling	Physical load monitoring, fatigue prediction, performance trend analysis
ST-GCN	Skeleton-based spatiotemporal feature learning	Gymnastics, diving, martial arts quality assessment
Transformer	Long-range global dependency capture	Game situation understanding, tactical prediction, player trajectory mining
Multimodal Fusion Network	Heterogeneous data alignment & integration	Comprehensive performance evaluation, decision-making fusion
Reinforcement Learning	Sequential decision optimization	Real-time tactical selection, game command, resource allocation

B. RECURRENT NEURAL NETWORKS (LSTM/GRU/TCN)

Recurrent neural networks are adept at modeling temporal dependencies and are suitable for continuous action understanding, physiological signal temporal analysis, load change prediction, performance trend deduction, and fatigue state recognition. LSTM and TCN can effectively capture dynamic patterns in long-term motion sequences, improving the accuracy of temporal prediction and state evaluation.

C. SPATIOTEMPORAL GRAPH CONVOLUTIONAL NETWORK (STGCN)

STGCN regards the human skeleton as a topological structure, while modeling spatial topological relationships and temporal dynamic changes, which is very suitable for continuous action recognition, action quality assessment, and technical defect detection in gymnastics, diving, martial arts, dance and other evaluation and classification projects. It can accurately understand joint motion constraints and improve the accuracy of complex motion analysis.

D. TRANSFORMER NETWORK

The self attention mechanism based on Transformer can model global information in long sequences, and has good applicability in tactical analysis, global event judgment, performance changes in different time periods, and opponent strategy research on long-term game videos; For complex team sports such as ball games, global tactical deduction and victory prediction can be completed.

E. MULTIMODAL FUSION NETWORK

Multi source feature fusion networks can jointly represent features from different sources such as vision, inertia, physiology, trajectory, and environment, and complement each other in a unified representation domain to enhance the system's decision-making ability; The use of fusion methods helps to improve the system's anti-interference ability and robustness, and can provide more accurate motion state evaluation results and more reliable decision-making basis in complex competition environments.

F. REINFORCEMENT LEARNING MODELS

Reinforcement learning optimizes sequential decision-making via the Proximal Policy Optimization (PPO) algorithm. In tactical scenarios, the State Space (S) is defined by player coordinates and physiological fatigue levels; the Action Space (A) encompasses strategy shifts (e.g., pressuring vs. zone defense); and the Reward Function (R) is formulated as a weighted sum of scoring probability and energy expenditure minimization. By iterating through these parameters, the model generates optimal on-site adjustment strategies that outper form static rule-based systems in dynamic adversarial environments.

G. QUANTITATIVE ANALYSIS MECHANISM OF COMPETITIVE PERFORMANCE

Based on deep learning, end-to-end modeling of raw sports data is used to obtain intuitive and understandable game performance information: whether the actions are standardized, the degree of completion, whether the force is reasonable, what shortcomings exist, how much physical consumption is, whether feeling tired, how many tactics are used, the number of attacks, defenses, the probability of injury, and the level of game performance. Quantitative analysis enables the development of game performance from qualitative to quantitative, from general statements to specific numerical values, from one-time evaluation to continuous tracking, helping decision-makers form a data foundation that can be calculated, compared, and tracked.

H. MECHANISM OF AUXILIARY DECISION GENERATION

Assisted decision-making functions through a semantic translation layer. This layer utilizes an Expert Knowledge Graph (EKG) to bridge the gap between raw AI outputs (e.g., positional probabilities or joint angles) and actionable coaching insights. By mapping deep learning performance vectors onto a pre-defined rule base of sports science, the system translates abstract numerical data into concrete instructions, such as “lineup adjustments” or “movement corrections,” via a human-readable interface, tactical knowledge base, rule base, and optimization objectives through multi-objective constraint reasoning. Decision outputs include training adjustment suggestions, technical correction plans, tactical optimization strategies, risk warning information, rehabilitation regulation suggestions, personnel combination recommendations, etc. The decision-making system follows the principles of real-time, scientific, safe, and operable, ultimately forming a closed-loop control mechanism of “analysis decision execution feedback”.

IV. ANALYSIS METHOD OF SPORTS PERFORMANCE BASED ON DEEP LEARNING

A. ASSESSMENT METHODS FOR ACTION QUALITY AND TECHNICAL EFFICIENCY

Action quality assessment is the main requirement for scoring and technical projects. The process of action evaluation based on deep learning involves obtaining 2D/3D skeleton keypoints from pose estimation models, modeling skeleton temporal features using STGCN or Transformer models, and mapping action sequences to indicators such as action standardization, completion quality, force coordination, pose error, and technical defects. The model learns from expert ratings, automatically provides objective and accurate ratings for athletes, and points out incorrect movements and error locations for subsequent correction and use, as shown in Table 2.

B. MONITORING METHODS FOR PHYSICAL LOAD AND PHYSIOLOGICAL STATUS

Physical function and fatigue state directly determine athletic performance and injury risk. Using LSTM/TCN as a framework, a temporal model is established to dynamically model multiple sources of information such as heart rate, acceleration, training volume, sleep, and recovery of athletes. The acute load, chronic load, fatigue index, recovery status, and physical reserve of athletes are calculated in real time, and overtraining trends and hidden fatigue are observed. The effect of early warning can provide scientific guidance for training load and recovery methods.

C. METHODS FOR TACTICAL PATTERN RECOGNITION AND ANALYSIS OF OFFENSIVE AND DEFENSIVE EFFECTIVENESS

The tactical analysis of team competition projects is relatively complex. By using multi-objective tracking and graph neural networks, player trajectories, running positions, passing relationships, formations, marking ranges, offensive/defensive strategies, and other information can be automatically obtained, and tactical classification, tactical completion rate calculation, gap judgment, and opponent tactical preferences can be carried out. Further combining deep learning methods to process the above data, forming tactical efficiency evaluation results, analyzing their own offensive and defensive characteristics and shortcomings, and guiding targeted training in the next step.

D. METHODS FOR PREDICTING COMPETITIVE PERFORMANCE AND DEDUCING WINNING AND LOSING TRENDS

Using a multimodal Transformer based on historical records, opponent data, physical condition, weather conditions, combat style, etc., a competition ability prediction model is established to obtain predicted values such as scores, rankings, completion rates, and win rates. It can also achieve pre match drills, simulate playing styles, predict opponent movements, and assist in formulating competition plans, personnel combinations, and decision-making for playing style adaptation.

TABLE 2. Multisource Data Types and Quantitative Indicators for Sports Performance

Data Modality	Typical Data Sources	Analysis Dimension	Quantitative Indicators
Visual Video	Monocular camera, multi-view video	Technical movement, action quality	Accuracy, completion score, gesture error
Inertial Sensor	Accelerometer, gyroscope	Kinematics, motion intensity	Velocity, acceleration, power, impact force
Physiological Signal	Heart rate, sleep, recovery	Physical load, fatigue	ACWR, fatigue index, recovery state
Trajectory & Tactical	Position, formation, passing network	Tactical efficiency, offensive/defensive effect	Success rate, coverage, vulnerability
Injury-Related	Movement pattern, load history	Injury risk	Risk probability, early warning recall

E. RISK WARNING AND SAFETY ASSESSMENT METHODS FOR SPORTS INJURIES

Based on data such as movement posture, temporal load, historical injuries, and technical defects, an anomaly detection and classification model can be constructed to achieve intelligent early warning of acute injuries (sprains, strains) and chronic strain risks. The model outputs risk levels, high-risk actions, high-risk periods and intervention suggestions to help coaches adjust training plans in advance, avoid injury and disease risks, and ensure athletes' sports life and training safety.

V. DESIGN OF A DEEP LEARNING DRIVEN COMPETITIVE SPORTS DECISION-MAKING SYSTEM

A. OVERALL SYSTEM ARCHITECTURE

This study constructs a seven layer integrated decision support system consisting of a perception layer, data layer, representation layer, parsing layer, decision layer, application layer, and feedback layer. The perception layer is responsible for multi-source data collection; The data layer is responsible for storage and preprocessing; The representation layer is responsible for deep feature extraction; The parsing layer is responsible for five core analysis tasks; The decision-making level is responsible for intelligent reasoning and scheme generation; The application layer provides visualization services for coaches, athletes, and researchers; The feedback layer achieves effect tracking and model iteration, forming a closed-loop intelligent system.

B. CORE FUNCTIONAL MODULES

1) Action technique analysis and training optimization decision-making

This module automatically identifies deviations in movements, technical errors, and improper exertion, and develops personalized correction methods and phased training tasks. It provides correct demonstration videos, error feedback information, recommended training intensity, and tracks and evaluates the correction situation to provide users with targeted, personalized, and intuitive training guidance.

2) Tactical analysis and on-site command decision-making

The tactical module provides real-time analysis of opponent tactics, attack and defense vulnerabilities, and player running efficiency. It automatically recommends the optimal tactical plan, personnel adjustment suggestions, and on-site response strategies. Combined with a visualized situation screen, it achieves realtime, scientific, and efficient on-site command.

3) Physical load and rehabilitation regulation decisions

This module dynamically monitors load, fatigue, and recovery status, warns of overtraining and injury risks, provides recovery plans, rehabilitation plans, and regression training recommendations, and achieves a dynamic balance between training safety and competitive improvement.

4) Prediction of Competitive Performance and Decision making for Competition Optimization

Based on historical statistical data, estimate the athletes' competition results and winning rates, and provide the best list of participants, playing style suggestions, and lineup configuration to improve the scientificity of pre event preparation work.

C. DATA VISUALIZATION AND COMMAND CENTER

The system provides a unified visual large screen, displaying real-time indicators, action curves, tactical situa tions, risk warnings, and decision-making suggestions, achieving one-stop, intuitive, and real-time command and management, as shown in Table 3 below.

D. SYSTEM WORKFLOW

The entire execution process of the model is: information input $\rightarrow$ information processing $\rightarrow$ feature representation $\rightarrow$ performance quantification analysis $\rightarrow$ multi-objective inference and judgment $\rightarrow$ decision recommendation generation $\rightarrow$ implementation promotion $\rightarrow$ result feedback $\rightarrow$ cyclic correction. Realize full process automation, real-time, closed-loop, fast, reasonable, and effective.

E. KEY POINTS OF ENGINEERING IMPLEMENTATION

This system adopts a cloud-edge collaborative architecture, where heavy training occurs on the cloud while real-time inference is deployed at the edge. To mitigate the inherent latency of complex models like Transformers, we implement INT8 quantization and TensorRT-based layer fusion to optimize the multisource data pipeline. This strategy ensures that the processing of heterogeneous visual and sensor data maintains a latency below 50ms, thereby supporting the "real-time" on-site command promised in this framework; Unified access to different terminals; Strengthen data security, privacy, and permission control; The project is reusable

TABLE 3. Functional Modules of the AI-assisted Decision System

Core Module	Analysis Function	Output Decision	Application Scenario
Movement & Training Analysis	Action error detection, quality scoring	Personalized training plan, correction guidance	Daily training, technique optimization
Tactical Analysis & Command	Tactical recognition, opponent mining	Real-time strategy, formation adjustment	Competition, training match
Physical Load & Rehabilitation	Load monitoring, injury early warning	Recovery plan, risk control	Training regulation, injury prevention
Performance Prediction	Score, rank, winning rate	Player optimization, strategy matching	Pre-competition preparation
Visual Dashboard	Real-time status, early warning	Overall situation display, report output	Coach command center

and quickly portable, with high practicality, stability, and universality.

VI. EMPIRICAL RESEARCH AND EFFECTIVENESS VERIFICATION

A. EXPERIMENTAL DESIGN

This article conducts a 12-week experimental verification involving 60 professional athletes (N=60, balanced across athletics, basketball, and gymnastics). The participants were randomly assigned into two groups: the Experimental Group (EG, n=30), utilizing the deep learning-assisted system, and the Control Group (CG, n=30), following traditional experience-based coaching. All groups maintained identical training frequencies and intensities to ensure the baseline consistency for subsequent performance growth and injury rate comparisons.

B. EVALUATION INDICATOR SYSTEM

The evaluation indicators include accuracy of action recognition, correlation coefficient of action quality assessment, accuracy of competitive performance prediction, recall rate of injury warning, accuracy of tactical recognition, improvement of training efficiency, decrease in injury incidence rate, satisfaction of coaches and researchers, etc.

C. EXPERIMENTAL RESULTS AND ANALYSIS

The final system's action recognition accuracy is 92.7%, the game state recognition accuracy is 88.3%, the injury alarm recall rate is 89.5%, and the accuracy of tactical recognition is superior to other algorithms; The training time of the experimental group athletes decreased by 28.6%, the number of injuries decreased by 32.4%, and the satisfaction level of the coaching staff was 91.2%. The difference in training efficiency and injury reduction between the EG and CG was statistically significant (Independent Samples t-test, $P< 0.001$, 95% CI [24.2%, 33.0%]). This indicates that the observed 28.6% reduction in training cycles is directly attributable to the precision of the DL-driven interventions rather than random variance. This model has the advantages of high reliability, good stability, and high efficiency, as shown in Table 4.

D. EMPIRICAL CONCLUSION

In summary, the experiment has verified the effectiveness of the sports competition performance evaluation and decision support system based on deep learning technology proposed in this paper. It can improve the evaluation level of sports competition performance and the training quality of athletes to a certain extent, and provide scientific basis for the competition decision-making process while avoiding corresponding risks. This method is applicable to various sports fields and has broad application prospects.

VII. OPTIMIZATION STRATEGIES, RESEARCH CONCLUSIONS, AND PROSPECTS

A. OPTIMIZATION STRATEGY

In the future, further optimization can be achieved through multimodal deep fusion, small sample transfer learning, real-time deployment at the end, cross project generalization, human-machine collaborative decision-making, standard system construction, data security ethics, etc., to enhance the system's ability in complex scenarios, small samples, real-time performance, and universality, and promote technology to serve competitive sports practice more deeply.

B. RESEARCH CONCLUSION

This article proposes a deep learning based evaluation and decision-making method system for sports competition level, forming a technical path of perception representation quantification decision feedback. Based on this, the analysis of movements, physical fitness, tactics, risks, and predictions is carried out and decision-making suggestions are provided, which makes up for the previous method of relying solely on manual experience for judgment. The research results can provide theoretical, technological, and engineering support for the scientific, intelligent, and personalized development of competitive sports, which is of great significance for promoting the self-improvement of sports technology in China.

C. FUTURE OUTLOOK

In the future, technologies such as digital twins, metaverse simulation training, brain computer interfaces, end cloud collaborative big models, and autonomous evolutionary decision-making can be further integrated to build a more accurate, real-time, intelligent, and personalized competitive sports training and decision-making ecosystem. This will comprehensively promote the high-quality development of competitive sports into a new stage of intelligent training, scientific decision-making, efficient improvement, and safe and controllable development.

TABLE 4. Experimental Results of the Proposed System vs. Traditional Methods

Evaluation Index	Proposed DL System	Traditional Manual Method	Improvement
Action Recognition Accuracy	92.7%	71.4%	+21.3%
Performance Prediction Accuracy	88.3%	65.2%	+23.1%
Injury Warning Recall Rate	89.5%	58.6%	+30.9%
Training Period Reduction	—	—	-28.6%
Injury Rate Reduction	—	—	-32.4%
Coach Satisfaction Score	91.2%	62.7%	+28.5%

AUTHOR CONTRIBUTIONS

Conceptualization –Jianchao Zhang, Jianjian Sun, Shiyang Li, Aichao Li, Tingting Ding and Xiang Zhang; methodology – Jianchao Zhang, Jianjian Sun, Shiyang Li, Aichao Li, Tingting Ding and Xiang Zhang; investigation – Jianchao Zhang, Jianjian Sun, Shiyang Li, Aichao Li, Tingting Ding and Xiang Zhang; writing-original draft preparation – Jianchao Zhang, Jianjian Sun, Shiyang Li, Aichao Li, Tingting Ding and Xiang Zhang. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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