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Artificial Intelligence in Sports: A Systematic Review of Theoretical Foundations, Technologies, and Applications

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ABSTRACT
Background. This systematic review critically examines the application and theoretical prospects of Artificial Intelligence (AI) in the field of sports through the perspectives of the theoretical foundations of AI. **Methods**. A comprehensive study of previous literature, involving the meticulous scrutiny of 2,368 articles, led to the methodical screening of 20 documents for review. The investigation prioritizes the analysis of computer algorithms and various technologies, with a particular emphasis on AI in sports. **Results**. The results indicated that Artificial Neural Networks (ANN) dominate the sports domain, showcasing a high frequency of utilization and underscoring the prevalent use of AI technology in this domain. **Conclusion**. The study methods were predetermined in a registered protocol on PROSPERO (registration number: CRD42024497839). Specifically, the data sources used in this study were limited to literature published from January 2011 to April 2024. In this process, the databases searched included Semantic Scholar, ScienceDirect, PubMed, and Scopus. After applying the inclusion and exclusion criteria, a total of 2368 articles were excluded, and consequently, only 20 articles were finally included for comprehensive analysis. Semantic Scholar, ScienceDirect, PubMed, and Scopus were searched in this study, and the main limitation lies in the possibility that data from other databases may have been omitted.

INTRODUCTION

The inception of the artificial intelligence (AI) discipline in 1956 marked the commencement of a period of rapid development for AI (1). In its early stages, the focus of AI research was on emulating the human brain and understanding natural language, primarily through machine learning and analysis (2, 3). Since the 1980s, the emergence of expert systems within AI has provided a practical solution for handling complex environments (2). Subsequently, various computer algorithms, including neural networks, fuzzy logic, and genetic algorithms, became prominent (4). Over time, the scope of AI applications has expanded, with academic research on AI experiencing significant growth between 2015 and 2019 (5).

The global dissemination of AI development and application has led to in-depth research by scholars and practitioners across diverse fields. The medical, transportation, manufacturing, finance, and other sectors contribute significantly to the rapid development of the industry (6, 7). Notably significant, the advent of ChatGPT in 2022 saw a transformative shift in the landscape of traditional AI, significantly enhancing human life (8).

In the current stage of AI development, technological advancements are showcased across various aspects, with notable progress in the field of human-computer interfaces (9). These advancements are prominently manifested in algorithmic advancements, such as statistical machine translation (SMT), example-based machine translation (EBMT), neural machine translation (NMT), and hybrid machine translation (HMT) (10). Beyond facilitating communication among individuals, machine translation assumes heightened significance for machines to comprehend human language, incorporating emotional interface (EI), gesture-based human-machine interface (GBHMI), and voice-based human-machine interface (SBHMI) (11-13). These developments empower machines to interpret human behavior through parameters such as tone, gestures, or body posture (14). The deployment of these computer algorithms not only resolves the interaction challenge between humans and machines but also advances computers' understanding of human commands (3, 15, 16). These algorithmic applications enrich the theoretical foundations of natural language understanding, addressing the intricacies of machine comprehension of human language, attitudes, and behavior, thereby facilitating effective human-computer interaction.

With the continuous advancement of AI, it has become increasingly integrated into the realm of sports (17). The application of AI in sports research offers sufficient theoretical support for its use within the sports domain. The research direction of AI in sports primarily emphasizes sports analysis, performance evaluation, sports data collection, formulation of diet plans, training plans, strategic planning, results and patterns prediction, sports data analysis, and decision support, among other aspects (18-20).

However, at this stage, the development of AI still faces numerous challenges. Specifically, in predicting athletes' injury risk, athletes operate in variable environments and possess different physical structures, including muscles, bones, nerves, and psychological factors, all of which contribute to the complexity of injury risk. Moreover, although existing reviews have summarized the application of AI in injury prediction (21), AI for analyzing athletes' injury risk remains immature, with research gaps persisting, including the integration of multimodal data, data consolidation, and the development of predictive models. Nevertheless, technologies such as machine learning and deep learning have already shown potential in predicting injury risk (22).

Currently, the involvement of AI in sports has yielded numerous practical and theoretical outcomes, leading to the swift incorporation of AI and sports (23). Pietraszewski et al. (2025) stated that AI demonstrates considerable potential in sports applications, primarily in the optimization and design of training programs, injury prevention, and sports decision-making (24). Specifically, the practical applications of AI in sports are grounded in the solid theoretical foundations of AI, including artificial neural networks, machine learning, machine vision, virtual reality, and augmented reality. These practical applications include intelligent tactical models for sports competitions, diversified data integration, and predictive models for sports performance. Thus, this investigation aims to methodically scrutinize and categorize the theoretical underpinnings of AI in sports, investigate the application of AI technology and algorithms in sports, and propose potential research opportunities to address the corresponding research gaps.

MATERIALS AND METHODS

Search strategy. To ensure the scholarly rigor of this study, the following databases, namely Semantic Scholar and ScienceDirect, have been selected for the literature review. To mitigate any potential data limitations, supplementary information was thoroughly screened from additional databases and incorporated into the final research corpus. Moreover, PubMed and Scopus served as supplementary databases for consultation purposes. For the search engine query, the study employed the following keywords: ("Sports" OR "Exercise") and ("Artificial Intelligence") and ("Theoretical Basis"). (for detailed search strings, refer to Appendix A).

Inclusion and exclusion criteria. The data source utilized in this review pertains solely to literature published from January 2011 to April 2024, and the search parameters were confined to the Inclusion/Exclusion and Quality Criteria, as detailed in Table 1.

Table1. Inclusion/Exclusion Criteria

Criteria	Details
Inclusion	1. Literature from 2011 onwards. 2. Literature titles, abstracts, and keywords include: sports. Exercise. Artificial intelligence. Adolescent health. 3. Types of literature: Article, Conference, Methodology paper, Books, and Electronic Sources. 4. Scope of search: Computer Science. Social Science, PubMed, and Scopus.
Exclusion	1. Case reports. 2. Abstract only studies. 3. Published in a language other than English.
Quality	1. The literature has a definite research method. 2. The literature has clear research results.

Initially, the systematic review adhered to the established Exclusion Criteria and thus eliminated a portion of the literature that was deemed unsuitable for this study. Subsequently, the review applied the Quality Criteria (25), which excluded literature that did not meet the criteria in Table 1. Ultimately, the review successfully identified the relevant literature that was deemed highly pertinent to this study.

The systematic review focuses on refining the scope of the literature search to align with the research topic, purpose, and specific keywords identified. The review emphasizes the need for careful exclusion criteria to ensure that the examined literature is both comprehensive and relevant. It specifically looks at studies published between 2011 and 2024 that explicitly reference sports, exercise, artificial intelligence, and theoretical foundations, while also being limited to the fields of computer science and social science. After applying these criteria, 2368 articles are found to be ineligible, and ultimately, only 20 articles are selected for comprehensive analysis. Additionally, the review pays close attention to the quality of the academic articles, with rigorous scrutiny of their research methodologies and findings. Articles that do not meet the defined quality standards are systematically excluded, resulting in the final selection of articles that meet the prescribed criteria.

Study Outcomes. The primary outcomes of this research encompassed the identification and

critical examination of key technologies employed in the application of artificial intelligence (AI) within the sports sector. Furthermore, the study meticulously consolidated insights to outline the prospective trajectory of artificial intelligence in sports. This study consolidates definitive research findings concerning the application of artificial intelligence in the sports domain, elucidating technological innovations and the expanded scope of AI algorithm applications. It comprehensively explores the Theoretical Foundations of artificial intelligence within the sports sector.

Building upon these Theoretical Foundations, the study puts forth potential development directions, innovations, and opportunities for artificial intelligence in sports. In essence, the research meticulously organizes the Theoretical Foundations of AI in sports, delineates key Theoretical Foundations, and outlines the prospective development prospects of AI in the sports domain, contributing to the ongoing innovation and advancement of AI in artificial intelligence.

Screening and Data Extraction. The evaluation followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol (Figure 1). The review's methods were predetermined in a registered protocol on PROSPERO (CRD42024497839). This systematic review meticulously applied pre-established criteria for the inclusion and exclusion of literature. The comprehensive assessment covered various aspects, including article type, title, and either the abstract or complete article content. Following this, data extraction was performed using a standardized form, encompassing information such as authors, country, type, sports application, field of sports, theoretical basis, and main findings. Prior to the actual data collection, the data were independently collected by the two authors of this study. Cohen's Kappa (κ) was used to assess inter-rater agreement among reviewers, showing high agreement (K = 0.82). In cases of differences in data extraction, the two authors engaged in in-depth discussions. If differences or disagreements could not be resolved, the third author intervened and facilitated the decision-making process.

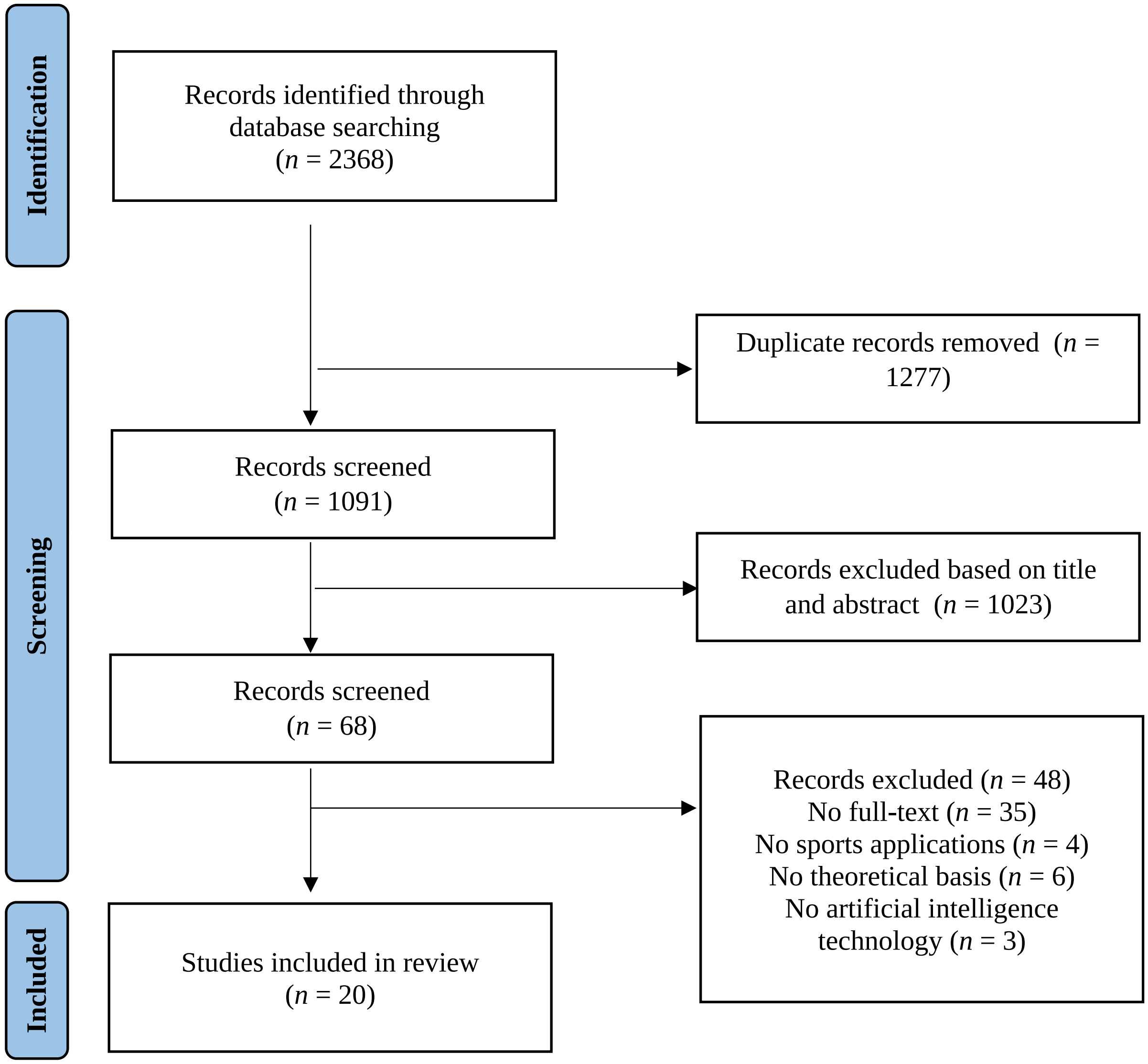

Figure 1. PRISMA flow diagram.

Quality Assessment. This study adopted the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines, proposed by von Elm et al. (2007), to assess the quality and risk of bias of the 20 included studies. The aim was to reduce content discrepancies and ensure the quality of the included research (26). The STROBE assessment covers the title, abstract, introduction, methods, results, and discussion sections, comprising a total of 22 items. Each item has three possible responses: Y = Available, P = Partly available, and N = Not available.

RESULTS

Quality assessment and analysis of publication bias. According to the STROBE statement (26), the quality and risk of bias of the 20 included studies were assessed, and the results are presented in Table 2. According to Table 2, the 20 references in this study were of moderate to above-average quality, with each article achieving a STROBE "Yes" score of 50% or higher, indicating a low risk of bias in the included literature.

Theoretical Basis in AI with Sports. AI machine learning algorithms have strong applicability and vast potential in the sports field. In particular, the addition of computer algorithms enables machines to perform real-time data display, analysis, and prediction for sports teams and athletes with ease. These applications are huge. It improves athletes' performance and coaches' tactical decision-making guidance (27, 28). The application of AI in sports has spread to many sports teams. The advancement of science and technology has an undeniable impact on sports performance. Moreover, AI has many unknown potentials in the sports field waiting to be tapped. In the future, there will be Great development prospects. At this stage, AI can be applied to injury prevention, sports data analysis, team data analysis, and other fields. The development of these applications is inseparable from the addition of computer algorithms. The addition of these computer algorithms can enable coaches to make informed decisions based on real-time data display, whenever possible. Reduce the occurrence of exercise risks.

Table 2. STROBE Statement (26), Checklist of items.

References	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Abdullah et al. (6)	Y	Y	Y	Y	P	P	Y	Y	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	P	Y	Y
Salim et al. (29)	Y	Y	Y	Y	P	P	Y	P	P	Y	P	P	Y	P	Y	Y	Y	Y	Y	P	Y	Y
Leung and Joseph (30)	Y	Y	Y	Y	P	Y	Y	Y	P	P	P	P	P	P	Y	Y	Y	Y	Y	Y	Y	Y
Connor et al. (31)	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y
Lopes et al. (32)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Hassan et al. (33)	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Peng and Kim (34)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Kang & Kang (35)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Liu et al. (18)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Liu et al. (36)	Y	Y	Y	Y	P	P	Y	Y	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mazurova et al. (37)	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	P	Y	Y	Y	Y	Y	N
Naraine & Wanless (38)	Y	Y	Y	Y	Y	Y	Y	P	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	N
Noori & Sadeghi (39)	Y	Y	Y	Y	P	P	P	P	P	P	P	P	P	P	Y	N	P	Y	P	P	Y	Y
Novatchkov & Baca (40)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Białecki et al. (41)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Ramkumar et al. (42)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Rein & Memmert (43)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Rodrigues et al. (44)	Y	Y	Y	Y	P	P	Y	P	P	P	P	P	P	P	Y	Y	Y	Y	Y	Y	Y	N
Schack et al. (45)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y
Xing et al. (46)	Y	Y	Y	Y	N	N	P	Y	N	N	P	Y	N	N	P	P	N	Y	Y	Y	Y	Y

1=Indicate the study's design with a commonly used term in the title or the abstract; 2=Explain the scientific background and rationale for the investigation being reported; 3=State specific objectives, including any prespecified hypotheses; 4=Present key elements of study design early in the paper; 5=Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection; 6=Give the eligibility criteria, and the sources and methods of selection of participants; 7=Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable; 8*=For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group; 9=Describe any efforts to address potential sources of bias; 10=Explain how the study size was arrived at; 11=Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why; 12=Describe all statistical methods, including those used to control for confounding.; 13*=Report numbers of individuals at each stage of study—e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed; 14*=Give characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders; 15*=Report numbers of outcome events or summary measures; 16=Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included; 17=Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses; 18=Summarize key results with reference to study objectives; 19=Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias; 20=Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence; 21=Discuss the generalizability (external validity) of the study results; 22=Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based. Y=Available; P=Partly available; N=Not available.

The realization of these applications is intricately linked to the incorporation of computer algorithms. The integration of these algorithms enables coaches to make swift decisions based on real-time data, thereby mitigating exercise-related risks to the greatest extent possible. This application of AI plays a significant role in maintaining player health and well-being, ultimately reducing the likelihood of injuries that could negatively impact performance. Table 3 includes 20 selected literature sources that encompass various theoretical bases, all of which are centered on the theoretical foundations of artificial intelligence in sports.

Table 3. The theoretical basis of AI in sports.

No.	Authors	Country	Type	Sports application	Field of sports	Theoretical basis	Main findings
1	Abdullah et al. (6)	Malaysia	Journal	Soccer	Predicting athletic performance	DEE. DL. ANN. SVMs. BMM. DTC. FLA. LR.	The AI predictive technology exhibits robust capabilities in forecasting player performance.
2	Salim et al. (29)	Ireland	Journal	Volleyball	Coaching, sports analysis, and sports science	ANN.DEE. MV.	Movement analysis is carried out through the use of AI combined with the ecological dynamics of sports behavior. The analysis is mainly reflected in individual movement analysis, player trajectory analysis, and group movement analysis.
3	Leung and Joseph (30)	Canada	Journal	football	Match outcome prediction	DM	The study identified a sports data mining method that can predict match outcomes with relatively high accuracy.
4	Connor et al. (31)	UK	Journal	Team sports	Athletic development and team performance.	DM. DEE. ML. CI.	Developing an optimal framework for future training programs.
5	Lopes et al. (32)	Brazil	Journal	Nutrition and fitness	Precision nutrition and fitness	DEE. ML.	AI was combined with sports fitness and nutrition, proposing accurate nutrition and fitness.
6	Hassan et al. (33)	Austria	Journal	Handball	Offensive tactical behavior	ML.MAT. ANN.	AI serves as a potent tool for evaluating the effectiveness of tactical training.
7	Peng and Kim (34)	China	Journal	Mental training	Mental training	ML	The efficacious advancement of psychological training for athletes.
8	Kang & Kang (35)	Korea	Journal	Physical education	Sports Experience, Rehabilitation, and Disabilities	VR	Artificial intelligence is involved in the Rehabilitation of people with disabilities in sports and diversifies the methods of exercise.
9	Liu et al. (18)	China	Journal	Season factors, teams, all-rounder, and batsmen	Sports data analysis and visualization	MV. SP. ANN.	Motion data collection and visualization based on the video-based effective visualization framework (VEVF) model.
10	Liu et al. (36)	China	Journal	PE class	Physical education	ANN. LSTM. DEE.MV.	AI improves physical education teaching methods through a human motion recognition model.

Table 3. continued.

11	Mazurova et al. (37)	Finland	Journal	Judges, gymnasts, coaches, federations, technology providers, and fans	Human judgment process in sports	MV. ML.	Artificial intelligence as an auxiliary tool to participate in sports refereeing and sports performance evaluation.
12	Naraine & Wanless (38)	USA	Journal	sports marketing	Sports management	NLP.	The application of AI to sports management is mainly reflected in: 1) Collecting customer information. 2) Intelligent sales process. 3) Intelligent computer platform. 4) Self-operating service.
13	Noori & Sadeghi (39)	Iran	Journal	Volleyball	Talent identification	CLA.	Identification of sports talents based on a fuzzy logic approach.
14	Novatchkov & Baca (40)	Turkey	Journal	Basketball	Result prediction model	ANN. FLA. CLA. DM.	Evaluation of strength training based on a fuzzy logic approach.
15	Białecki et al. (41)	Poland	Journal	Video games	Video games and esports	AR. VR	Artificial intelligence uses VR and AR technology in eSports.
16	Ramkumar et al. (42)	USA	Journal	Athlete injury risk	Orthopedic surgery and sports medicine	DEE.ML	AI in sports medicine can predict athlete injury risk, assess athlete injuries, and aid in physical exams.
17	Rein & Memmert (43)	Germany	Journal	Soccer	Sports science, modeling of tactical decision-making	ANN. DTC. MP. SVMs.	Incorporate big data technology into advanced football research to formulate theoretical frameworks for enhancing tactical decision-making.
18	Rodrigues et al. (44)	Portugal	Journal	Futsal	Athletic performance	BMM. ANN. DEE. LSTM	AI pattern recognition in a sports environment.
19	Schack et al. (45)	UK	Journal	Virtual, augmented, and mixed realities	Sport psychology	AR. VR. MR	Through AR, VR, and MR technologies, combined with Attentional, auditory, and brain-related technologies, to enhance the psychology of athletes.
20	Xing et al. (46)	China	Journal	Sports video	Multiple object tracking	BIA.	Proposing multiple object tracking (MOT), which can track multiple athletes.

Artificial Neural Networks (ANN) are machine learning algorithms designed to simulate the functions of the human brain (20). They are constructed with interconnected nodes that process information and make decisions based on that information (47). As a computer algorithm, Artificial Neural Network (ANN) boasts a broad spectrum of applications, encompassing image analysis, speech recognition, data extraction and analysis, natural language processing, and data prediction and analysis. Functioning as a potent algorithm, ANN is adept at extracting and analyzing various forms of data, including image data, video data, or human biological data. ANN can continuously deepen its own data understanding through data extraction and learning, and predict and analyse unknown data.

Machine learning (ML) is a computer technology that can accurately and quickly analyze and organize data. It is worth explaining that these data can be large and complex. ML can automatically obtain the desired data through algorithms or models and perform continuous mechanical output and input (48).

Machine vision (MV) is an innovative technology that utilizes computers to simulate human vision and extract, analyze, and interpret image data. This technology is currently widely used in automated manufacturing. It can identify defective products and be used in robot vision (49, 50). It can also be applied to areas where visual judgment is highly relevant, such as autonomous driving and medicine (51, 52).

VR is a computer-simulated virtual environment that immerses individuals within a digital setting. This environment affects human visual organs through high-definition screens, impacts auditory organs through sound systems, and synchronizes notifications and changes in the external environment through motion sensors, all to achieve the purpose of virtual imitation display (53).

This application has a wide range, spanning from sports entertainment to sports training and education. It enables participants to interact deeply with computers or engage in interactions with each other within a virtual environment (14). The ranking in Table 4 is based on the frequency of occurrence of each theoretical basis within the literature sources summarized in this study.

Table 4. Ranking of the theoretical basis in artistic intelligence with sports

Abbreviation of the theoretical basis	Theoretical basis	Ranking of frequency
ANN	Artificial neural network	7
ML	Machine learning	4
MV	Machine vision	4
VR	Virtual reality	3
DM	Data mining	3
SVMs	Support-vector machines	2
DTC	Decision tree classifier	2
FLA	Fuzzy logic approach	2
BMM	Bayesian Mixture Model	2
AR	Augmented reality	2
CLA	Classification logic approach	2
LSTM	Long short-term memory	2
DL	Deep learning	1
NLP	Natural language processing	1
MAT	Machine-aided techniques	1
MP	Markov process	1
LR	Logistic regression	1
CI	Computational intelligence	1
BIA	Bayesian inference approach	1
SP	Signal processing	1
MR	Mixed reality	1

Note. ANN: Artificial Neural Network. ML: Machine Learning. MV: Machine Vision. VR: Virtual Reality. AR: Augmented Reality. SVMs: Support-Vector Machines. DTC: Decision Tree Classifier. FLA: Fuzzy Logic Approach. BMM: Bayesian Mixture Model. DM: Data Mining. CLA: Classification Logic Approach. LSTM: Long Short-Term Memory. DL: Deep Learning. NLP: Natural Language Processing. MAT: Machine-Aided Techniques. MP: Markov Process. LR: Logistic Regression. CI: Computational Intelligence. BIA: Bayesian Inference Approach. SP: Signal Processing. MR: Mixed Reality.

Ranking of frequency: refers to the computer technologies used in the included articles, where each number represents the number of articles using that technology. For example, if the number for Artificial Neural Networks (ANN) is 7, it means ANN was used in 7 articles.

Counting rules: If an article applied one or more computer technologies, each technology was counted once. If the same technology appeared multiple times in a single article, it was still counted only once.

After thoroughly examining the data in Table 4, it is clear that eight fundamental theoretical foundations have been ranked fifth. These include Augmented Reality, Support Vector Machines, Decision Tree Classifier, Fuzzy Logic Approach, Bayesian Mixture Model, Data Mining, Classification Logic Approach, and Long Short-Term Memory. It is crucial to consider these foundations when conducting further research in this field. Table 4 also shows that there are nine theoretical bases ranked sixth, including Deep Learning, Natural Language Processing, Machine-

Aided Technologies, Markov Process, Logistic Regression, Computational Intelligence, Bayesian Inference Approach, Mixed Reality, and Signal Processing.

Theoretical basis in artificial intelligence. Early AI research faced many challenges, especially in natural language comprehension, human-computer interaction, computer vision, biometric identification, and virtual and augmented reality technologies. These obstacles significantly hindered AI development and required substantial effort to overcome (54). In its early stages, AI faced significant constraints, particularly in algorithmic design, data extraction, and limitations in computer hardware. Artificial Intelligence (AI) has achieved significant breakthroughs and advancements across diverse industries. However, realizing the full potential of AI requires increased involvement from academics and collaboration among various industry departments. This undertaking is characterized by its complexity and the enduring nature of the effort involved (55).

Natural Language Understanding. Machine Translation (MT), Semantic Understanding (SU), and Question Answering System (QAS) function as three foundational modules that collectively constitute Natural Language Understanding. The evolution of Natural Language Understanding contributes to enhancing computers' comprehension of human language and behavior, reflecting a process of continuous learning across various levels. The advancement of MT plays a pivotal role in facilitating the integration of multiple languages. Through MT intervention, real-time translation of diverse languages becomes feasible, demonstrating considerable accuracy. The theoretical foundations of MT encompass the machine translation protocol, example-based machine translation (EBMT), hybrid machine translation (HMT), neural machine translation (NMT), and statistical machine translation (SMT) (56).

Semantic Understanding (SU) requires computers to mimic human behavior by collecting data on human speaking styles, sentence meanings, and sentence characteristics in various regions and conducting analysis to ensure that translations between multiple languages can minimize sentence understanding deviations and accurately input and output different human languages (57). The enhanced comprehension provided by Natural Language Understanding signifies a significant leap in advancing computers' abilities to comprehend human language and behavior. This understanding is not limited to word-for-word translations but extends to an encompassing grasp of the semantic and pragmatic dimensions of language, fostering rich intercultural communication and understanding across linguistic boundaries.

Machine vision technique. Machine Vision Technology, a computer-based technology capable of emulating human image extraction and capture, currently encompasses video technology, image technology, and three-dimensional space technology. The emergence of machine vision techniques has enhanced the computer's ability to mimic human perception. This technology represents a crucial development in the field of AI, demonstrating strong practicality in both commercial and medical applications. The algorithms of the Machine Vision technique play a crucial role in enabling the extraction of data from images. This technology not only analyzes and extracts image data but also includes functions such as clarity enhancement and image restoration. The Machine Vision technique is a computer algorithm that serves as a technology for obtaining image data. Differing from previous image processing techniques, this technology has a vast range of applications, including security intelligent monitoring, vehicle guidance, and robot control, among others (58, 59).

The emergence of 3D vision technology has brought innovative changes to the digital field. It is a diverse and complex computer algorithm that utilizes graphical modes to create and obtain 3D data, establishing three-dimensional models. This represents a transformation in the interactive methods within the digital field, providing accurate information output for the models (60).

Biometric Identification. Biometric Identification represents a breakthrough in AI, utilizing computer algorithms to acquire and comprehend human body characteristics. The contribution of this technology lies in enabling humans to conduct more in-depth research on organisms through computer applications, fostering a better understanding of biological features. This technology has a wide range of applications, detecting the distribution of veins through the skin surface and identifying human faces. It represents a significant breakthrough in biometric tools, exhibiting higher accuracy compared to traditional physical identification methods, particularly in counterfeit prevention. This technology holds crucial applications for human safety, financial security, and identity security (61). Voiceprint recognition technology is a component of Biometric Identification technology, capable of extracting and analyzing human voice data and exhibiting sensitivity to music and sounds (62).

The application scope of Biometric Identification technology is diverse, and its technology is also diverse. Its technology involves voiceprint recognition, gait recognition, and other biometric methods. In terms of application, it is primarily used for various purposes in safety and medical contexts (63, 64). The development of Biometric Identification technology has a significant impact on the entire society. It has changed our traditional modes of travel and lifestyles. However, it is worth noting that the development of Biometric Identification technology may pose potential security risks, such as the misuse of our personal Biometric Identification information. Therefore, developers need to have a strong sense of ethical and moral awareness.

Human-machine interaction. Speech-based human-computer interaction (SBHMI) is a computer technology that recognizes human speech through computers and provides real-time feedback to the speech. This feedback is expressed in understanding human language and making corresponding replies. It is a major technological innovation enabling human-computer interaction (16). SBHMI technology not only enhances people's lifestyles by relieving manual burdens but also serves as an auxiliary tool for individuals with disabilities, thereby simplifying their daily lives.

Gesture-based Human-Computer Interaction (GBHMI) constitutes another computer technology similar to SBHMI, differing in that GBHMI analyses human body movements through sensors worn by individuals (65). GBHMI finds applications in various environments, including athlete technology detection and correction, as well as human-computer interaction.

In the domain of human-computer interaction, both SBHMI and GBHMI stand out as innovative technologies with substantial developmental prospects. The progress in technology related to emotional interaction is truly remarkable. This advancement enables the devices and interfaces we use to understand and respond to our emotional states, enhancing the user experience to be more personalized and efficient (10).

DISCUSSION

The theoretical bases are all of utmost significance. However, the frequency of their usage in the 20 selected articles cannot be considered an indicator of their relative importance. The ranking presented here is solely based on the application of AI technology in the context of sports. A high frequency of usage of a particular theoretical foundation suggests that AI has a wide range of applications in the field of sports and is more intricately involved in this domain. Conversely, the lower ranking of certain AI technologies should be seen as a testament to their high potential in the field of sports.

Through AI analysis, this systematic review identified significant interconnections across various fields, particularly in sports, showcasing numerous applications. Additionally, AI demonstrates substantial applications in medical health, addressing conditions such as cardiovascular diseases, obesity, diabetes, and other ailments. Furthermore, the validity rate of these effects remains consistently high (66). In light of the COVID-19 pandemic and the subsequent reduction of physical activity, the impact of AI on both physical and mental health has become increasingly pronounced (67).

The advent of AI has presented theoretical opportunities for numerical research in human health (68). Furthermore, AI has a rich theoretical foundation, especially with significant developments in the field of sports (69, 70). Machine Vision (MV), Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) form the applied foundations for computer vision (71-73). Natural Language Processing (NLP) and Speech-Based Human-Machine Interface (SBHMI) are the foundational applications that enable computers to understand human language (74). Long Short-Term Memory (LSTM), Computational Intelligence (CI), and Gesture-Based Human-Machine Interaction (GBHMI) form the foundation for computers to understand human cognition (9, 75). These AI technologies in sports can provide intelligent virtual scenes, virtual characters, language interactions, body pose correction, training method guidance, competition references, and sports diet plans, among other features (19).

AI has diversified development in the field of sports, playing a crucial role in sports medicine, sports training, and sports education. Sports medicine has become an emerging field. At the current stage, AI in sports medicine can not only predict athlete injuries and improve athlete performance, but also assist doctors, physiotherapists, and trainers throughout the entire clinical practice (76). It is worth noting that the application of computer technologies in sports has promoted the democratization of knowledge, as reflected in the increased sharing of knowledge in the fields of sports training and sports education (77). As computer technologies are integrated into sports, particularly in fields such as sports analysis and sports biomechanics, the field is undergoing a huge transformation that facilitates the integration of big data and offers more opportunities for the application of AI in sports (78).

However, attention should be given to the drawbacks of AI in the sports domain, especially concerning the younger population (79). For instance, the use of VR and AR scenarios or gaming experiences may lead to visual fatigue, dizziness, and addiction among adolescents (80). Furthermore, AI in the field of sports utilizes data sensors, and these AI sensor devices have their limitations. Firstly, the material of AI sensors may induce allergies in some individuals (81). Secondly, when the AI sensor is connected to the human body, it may cause friction on the skin, leading to skin abrasion. Therefore, the development of AI in the sports domain should also thoroughly consider the potential negative effects it may bring (82).

This study meticulously selected and analyzed 20 articles from a pool of 2368 research documents, employing statistical methods to scrutinize the theoretical foundations of AI. The pervasive integration of AI across various industries, especially in sports, signifies substantial developmental potential and prospects. The merit of this study lies in its capacity to unveil the theoretical underpinnings of AI within the sports domain, thereby providing a robust theoretical foundation for the future development of AI in sports. Consequently, the review recommends strengthening the theoretical foundation of AI sports and overcoming its current limitations by drawing on successful experiences from similar fields.

This study conducted a comprehensive investigation into the Theoretical Foundations of Artificial Intelligence in Sports, screening 2,368 articles and ultimately selecting 20 documents. The literature review revealed diverse Theoretical Foundations of Artificial Intelligence in Sports, including ANN (Artificial Neural Network), ML (Machine Learning), MV (Machine Vision), VR (Virtual Reality), AR (Augmented Reality), SVMs (Support-Vector Machines), DTC (Decision Tree Classifier), among others. A systematic analysis of these Theoretical Foundations indicated significant applications, particularly in ANN, ML, MV, and VR within the sports domain.

Looking ahead, AI is poised for further development. Natural Language Understanding will enhance computers' ability to comprehend human language and interpret movement behaviors in sports. Machine vision technology will facilitate the extraction and analysis of data from moving images in sports. Biometric Identification, leveraging computer algorithms, will analyze human body characteristics during physical activity. Human-machine interaction will involve computers identifying human movements, analyzing emotions, and interpreting tone.

CONCLUSION

However, from the perspective of research limitations, the results of this study indicate that ANN appeared most frequently, suggesting that it was more prevalent within the scope of this study and may also imply that ANN technology is more widely used in sports applications. As for other fields, such as medicine, transportation, and industry, the application situation of ANN technology and other computer technologies, including those with high and low frequencies, remains unclear in this study. Therefore, the fact that ANN appeared most frequently in this study does not mean that ANN technology is widely used in all fields. It is worth noting that many computer technologies in this study appeared with low frequency, such as DL, NLP, MAT, MP, LR, CI, BIA, SP, and MR; however, this does not mean that these technologies are outdated. On the contrary, the application of AI in sports is still in its early stages, and many technologies have not yet been fully applied, which also indicates that these computer technologies still have great potential in sports applications.

To conclude, this systematic review critically examines the theoretical prospects of artificial intelligence (AI) in sports, exploring various technologies and algorithms that are relevant to the field. It establishes a theoretical foundation and guidance framework for the future application of AI in sports. The study highlights the pivotal role of artificial intelligence in the sports domain and proposes potential applications for mitigating sports risks, enhancing technical and tactical strategies, improving team skills, and facilitating post-sports rehabilitation in the future sports landscape.

APPLICABLE REMARKS

- The systematic review conducted a systematic investigation into the theoretical foundations, technologies, and applications of AI in sports, and overall, the findings demonstrate strong applicability.
- The review summarizes the fundamental technologies related to the application of AI in sports and further analyzes the frequency of their applicability, thereby providing potential theoretical research opportunities for future development.
- By integrating AI from a sports-oriented perspective, this systematic review consequently contributes to the interdisciplinary integration of AI in sports, while also offering theoretical support and potential opportunities for the development of AI in sports.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Zhutang Liu, Garry Kuan. Acquisition of data: Zhutang Liu, Ke Zhou. Analysis and interpretation of data: Zhutang Liu, Yee Cheng Kueh. Drafting of the manuscript: Zhutang Liu. Critical revision of the manuscript for important intellectual content: Zhutang Liu, Garry Kuan. Statistical analysis: Zhutang Liu, Yee Cheng Kueh. Administrative, technical, and material support: Zhutang Liu. Study supervision: Yee Cheng Kueh, Garry Kuan, Ke Zhou.

CONFLICT OF INTEREST

The authors declare that there is no actual or potential conflict of interest regarding the publication of this systematic review. The writing, analysis, and publication of this study were conducted independently and were not influenced by any organization or individual.

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ETHICAL CONSIDERATION

The literature review was conducted in accordance with the guidelines of the Declaration of Helsinki. The ethical approval was granted by Universiti Sains Malaysia's Human Research Ethics Committee (USM/JEPeM/23040346). Additionally, this literature review has been registered in the PROSPERO database under CRD42024497839.

ROLE OF THE SPONSOR

No sponsor.

ARTIFICIAL INTELLIGENCE (AI) USE

No AI use.

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