INTJORASS (2026) 10(1) 26-34
RESEARCH ARTICLE
DOI: 10.46463/ijrss. 1777164

e-ISSN: 2618-5717
https://dergipark.org.tr/en/pub/ijrss
intjorass@gmail.com

International Journal of Recreation & Sports Science

Year : 2026
Volume: 10
Issue : 1
Pages :26-34

Artificial Intelligence and Virtual Reality in Sports Training: A Systematic Review on Skill Acquisition and Perceptual–Motor Performance

Ali Rıza Atıcı[1]

[1]Aksaray University, Faculty of Sport Sciences, Aksaray-Türkiye, https://orcid.org/0000-0001-9983-4213, atici.alrz@gmail.com

Corresponding Author: atici.alrz@gmail.com

Please cite this paper as follows: Atıcı (2026). Artifical Intelligence and Virtual in Sports Training: A Systematic Review on Skill Acquisition and Perceptual-Motor Performance. *International Journal of Recreation and Sport Science, 10* (1), 26-34. https://doi.org/10.46463/ijrss. 1777164

Article History

Received: 03.09.2025
Accepted: 02.02.2026
Available online: 16.02.2026

Edited By
Huseyin Gumus, Mersin University, Mersin, Türkiye

ABSTRACT

Artificial intelligence (AI) and virtual reality (VR) are increasingly integrated into sports training, yet evidence on their effectiveness remains fragmented. This systematic review synthesized experimental studies published between 2012 and 2025 on AI, VR, and hybrid AI+VR interventions for amateur, semi-professional, and professional athletes (youth to adults), following PRISMA 2020 guidelines. Six data-bases were searched, yielding 14 eligible studies. Results showed that VR interventions improved reaction time, decision-making, and balance, whereas AI programs enhanced learning efficiency and reduced errors. Hybrid approaches (n= 3) demonstrated the strongest sport-specific transfer effects, particularly in football and basketball. Regarding methodological quality, six studies presented a low risk of bias, five moderate, and three high. However, most interventions were short term with small samples, and heteroge-neity prevented meta-analysis. Overall, AI and VR hold considerable promise for enhancing motor learning and perceptual–motor performance, but more rigorous randomized controlled trials with standardized outcomes are needed.

Keywords: Virtual reality, Artificial intelligence, Motor learning, Perceptual– motor performance, Sys-tematic review

INTRODUCTION

The integration of digital technologies into sports sciences has accelerated remarkably over the last decade, leading to substantial changes in training methodologies (Neumann et al., 2017; Faure et al., 2020). Artificial intelligence (AI) and virtual reality (VR)-based applications are increasingly employed not only for performance assessment but also for enhancing skill acquisition and perceptual–motor performance in athletes (Le Noury et al., 2022). This growing trend has opened up novel avenues for research in both training science and sport psychology.

Artificial intelligence (AI), through machine learning and big data analytics, enables detailed monitoring and evaluation of individual performance. AI-based systems can analyze athletes' movement patterns, detect technical errors, and provide real-time adaptive feedback, thereby supporting personalized training prescriptions and workload management decisions (Mateus et al., 2024).

Moreover, machine learning techniques have been used to predict daily recovery status and personalize training load and goals, showing higher efficiency compared with traditional fixed programs (Rothschild et al., 2024). These adaptive features, combined with AI-driven video feedback tools, contribute not only to the development of physical skills but also to the enhancement of decision-making and perceptual–motor processes (Bridgeman et al., 2023).

Beyond performance monitoring and workload management, these AI-driven processes are directly relevant to skill acquisition and perceptual–motor performance. By continuously analyzing movement patterns and performance errors, AI systems can optimize practice conditions, regulate task difficulty, and provide timely feedback, all of which are core mechanisms underpinning motor learning and the development of perceptual–motor skills. Consequently, AI-based monitoring tools should not be viewed solely as diagnostic or management instruments, but also as active contributors to athletes' learning processes and performance adaptation.

Virtual reality (VR) applications, on the other hand, provide immersive, safe, and motivating training environments that enhance technical accuracy, reaction time, and decision-making abilities (Pagé et al., 2019). In team sports, VR facilitates realistic simulation of match scenarios, contributing to the development of perceptual–motor performance (Faure et al., 2020). In individual sports such as tennis and archery, VR-supported training has been reported to improve attentional focus, concentration, and technical precision (Le Noury et al., 2022). Importantly, the effectiveness and functional role of VR-based training may differ between team sports and individual sports due to their distinct perceptual–motor demands. In team sports, VR is primarily used to simulate dynamic, information-rich environments that require rapid decision-making, anticipation, and perception–action coupling under time pressure. In contrast, VR applications in individual sports tend to focus more on technical precision, attentional control, and the refinement of self-paced motor skills within relatively stable environments. These distinctions are well established in the literature and suggest that VR should not be considered a uniform intervention across sport types, but rather a context-sensitive tool whose learning effects depend on sport-specific perceptual and motor constraints (Faure et al., 2020; Le Noury et al., 2022).

While the term "motor skills" has traditionally been used in sports sciences, contemporary research increasingly emphasizes the broader constructs of "skill acquisition" and "perceptual–motor performance" (Pinder et al., 2011; Renshaw & Chow, 2019). These terms extend beyond physical movement accuracy, encompassing cognitive decision-making, visual perception, and attentional control. Thus, evaluating the effects of AI and VR-based interventions requires a holistic approach that transcends traditional notions of motor skills. In this context, it is important to distinguish between perceptual–motor performance and perceptual–cognitive processes. Perceptual–motor performance refers to the integrated execution of perception and movement, reflecting how sensory information is coupled with motor actions in real time. In contrast, perceptual–cognitive processes (e.g., decision-making, anticipation, visual search) represent underlying cognitive mechanisms that support, but are not equivalent to, perceptual–motor performance. Accordingly, perceptual–cognitive measures in this review are considered components or indicators contributing to perceptual–motor performance, rather than independent outcome constructs.

Although numerous individual studies have demonstrated the beneficial effects of AI and VR on balance, coordination, reaction time, and learning speed (Bideau et al., 2010; Neumann et al., 2017), these investigations are often limited by small sample sizes and methodological heterogeneity. Moreover, there is currently no systematic review that collectively examines both AI and VR technologies. Therefore, the present study aims to systematically review the effects of AI and VR-based exercise and training interventions on skill acquisition and perceptual–motor performance in athletes.

Despite the increasing number of studies examining artificial intelligence (AI) and virtual reality (VR) applications in sports training, several important gaps remain in the existing literature. First, prior research is highly fragmented, with substantial variation in sport disciplines, intervention characteristics, outcome measures, and methodological rigor, which limits the ability to draw integrated conclusions. Second, existing reviews have predominantly focused on VR-based interventions or have addressed immersive technologies in a broad manner, without systematically incorporating AI-driven adaptive training systems. Third, there is a clear lack of systematic reviews that specifically target athlete populations and simultaneously examine skill acquisition and perceptual–motor performance outcomes. As a result, the relative and combined effectiveness of AI, VR, and hybrid AI+VR interventions on athletes' learning and performance remains insufficiently understood.

Therefore, the present study aims to systematically review experimental studies investigating the effects of AI, VR, and hybrid AI+VR interventions on athletes' skill acquisition and perceptual–motor performance, in accordance with PRISMA 2020 guidelines

METHOD

This systematic review was conducted in accordance with the PRISMA 2020 guidelines (Page et al., 2021). Eligible studies were experimental in design and investigated the effects of artificial intelligence (AI), virtual reality (VR), or hybrid AI+VR interventions on skill acquisition and perceptual–motor performance in athletes. For the purposes of this review, the term experimental design was used to include both randomized controlled trials and quasi-experimental studies. Randomized controlled trials were defined as studies in which participants were randomly allocated to intervention and comparator groups. Quasi-experimental studies were defined as intervention studies that lacked random allocation but included a structured comparison, such as non-randomized control groups or pre–post designs. This distinction between randomized and quasi-experimental designs was applied during study selection and was explicitly considered in the methodological quality assessment. Participants included amateur, semi-professional, or professional athletes of any age group, while clinical, rehabilitative, or non-athlete samples were excluded. Interventions had to involve structured training protocols, and only studies that reported relevant performance outcomes were included.

A comprehensive search was conducted in PubMed, Scopus, Web of Science Core Collection, SPORTDiscus, PsycINFO, and IEEE Xplore, covering the period between January 2012 and August 2025. Boolean search strings combined terms such as "virtual reality," "artificial intelligence," "skill acquisition," "motor learning," and "perceptual–motor performance." Reference lists of included studies and related reviews were also screened. Although no language restrictions were applied during the search, only articles published in English were included in the final synthesis.

All retrieved records were screened independently by two reviewers. A total of 196 records were identified (184 from databases and 12 from other sources). After duplicates were removed, 142 studies remained. Following title and abstract screening, 114 were excluded, leaving 28 for full-text review. Of these, 14 were excluded for not meeting eligibility criteria, resulting in 14 studies included in the review. The full selection process is presented in the PRISMA flow chart (Figure 1).

Data from the included studies were extracted using a standardized form that recorded author, year, country, sport, participant characteristics, intervention type and duration, comparator condition, outcome measures, and key findings. Two reviewers conducted data extraction independently and resolved discrepancies through discussion.

Methodological quality was assessed using the Cochrane Risk of Bias 2.0 tool for randomized controlled trials and the Joanna Briggs Institute (JBI) checklist for quasi-experimental designs. These instruments evaluate aspects such as randomization, intervention fidelity, missing data, outcome validity, and reporting bias. Inter-rater agreement between reviewers was strong (Cohen's $\kappa = 0.81$), and disagreements were resolved by consensus.

Given the heterogeneity of interventions, sports, and outcome measures, a meta-analysis was not feasible. Outcome metrics varied widely across studies, including decision-making accuracy, technical precision, reaction time, and postural balance, which prevented statistical pooling. Therefore, a narrative synthesis was undertaken, grouping findings by intervention type (VR, AI, or hybrid) and sport discipline, and focusing on patterns of effectiveness compared with traditional or control training conditions. Athlete level (amateur, semi-professional, and professional) was extracted for all included studies and considered during the narrative synthesis. Due to the heterogeneity of study designs, sports, and outcome measures, no formal subgroup or comparative analyses by athlete level were conducted. Instead, differences in athlete level were descriptively examined to contextualize findings, and results were interpreted with consideration of whether interventions were applied in developmental (amateur/youth) or performance-oriented (semi-professional/professional) settings.

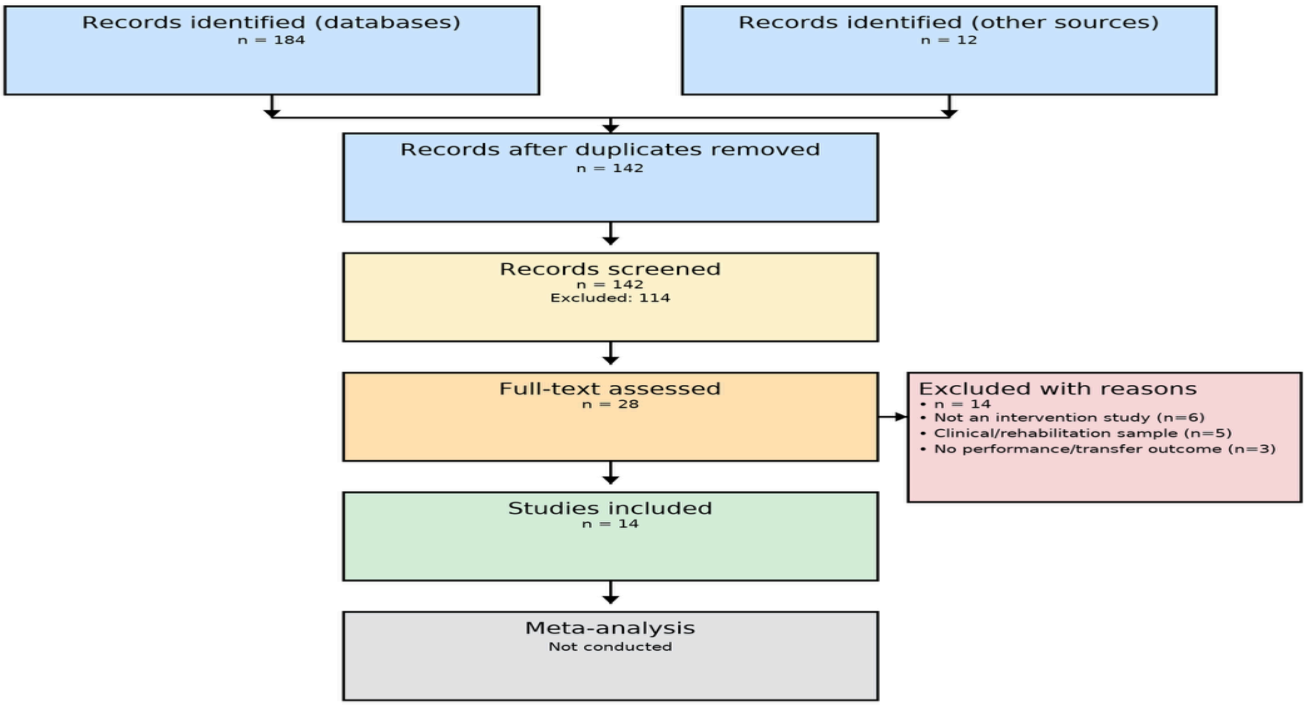

Figure 1. PRISMA Flow Chart

RESULTS

A total of 196 records were identified, including 184 from databases and 12 from other sources. After removal of duplicates, 142 unique records remained. Screening of titles and abstracts led to the exclusion of 114 studies, leaving 28 full-text articles for eligibility assessment. Fourteen of these were excluded because they were not intervention studies, included clinical or rehabilitation samples, or did not report performance outcomes. As a result, 14 studies were included in the systematic review.

The included studies were published between 2012 and 2025, with most conducted in the USA (n=4), China (n=3), Germany (n=2), and Australia (n=2). The most frequently studied sports were football (n=5), basketball (n=3), and tennis (n=2), while archery, swimming, volleyball, and ice hockey were each represented by one study. In terms of intervention type, 7 studies used VR, 4 employed AI, and 3 utilized hybrid AI+VR approaches. VR interventions mainly targeted decision-making, reaction time, and balance; AI-based programs emphasized learning efficiency and error reduction; whereas hybrid interventions showed promising effects in perceptual–motor integration, particularly in team sports such as football and basketball, although evidence is limited to a small number of studies (n = 3).

Quality appraisal revealed that 6 studies were judged to have low risk of bias, 5 had moderate risk, and 3 showed high risk. Inter-rater reliability between reviewers was high, with Cohen's κ = 0.81.

Table 1. Characteristics of the studies included in the systematic review

Author(s), Year	Country	Sport	Participants	Intervention (Type& Duration)	Comparator	Key Outcomes
Gray, 2017	USA	Baseball	80 high school players	Adaptive VR batting training, 6 weeks (2×45 min/week)	Repetition-based VR / on-field drills	Adaptive VR > others; significant transfer to real batting
Panchuk et al., 2018	Australia	Basketball	18 elite youth players	360° immersive video decision-making, 10–12 sessions (~2 weeks)	Standard practice	Improved decision-making and visual search; partial transfer
Pagé et al., 2019	Canada	Basketball	University varsity players	VR vs video simulation, 4 sessions	Video-based vs passive	Both improved; VR showed superior generalization
Fortes et al., 2021	Brazil	Soccer	26 youth players	VR decision-making training, 8 weeks	Video-based training	VR > video in decision-making and visual search
Harenberg et al., 2022	Germany	Soccer	Adolescent female players	3D-MOT VR training, multiple sessions	Control group	No significant difference; mixed evidence
Romeas et al., 2019	Canada	Multi-sport	57 active athletes	3D-MOT + decision-making VR, 4 groups	Single-task or control	Combined training influenced decision-making outcomes
Marshall et al., 2023	UK	Soccer (heading)	36 recreationa players	Immersive VR heading drills, 3 sessions (7–10 days)	No-training control	VR group improved heading performance & self-efficacy
Petri et al., 2019	Germany	Karate (kumite)	15 athletes	VR kumite response training, 10 sessions	Control	Improved reaction time and accuracy in kumite
Pastel et al., 2023	Germany	Karate (complex skills)	Adult amateurs	Immersive VR movement learning, multiple sessions	No trainer	VR enabled complex skill learning without trainer
Michalski et al., 2019	Australia	Table tennis	57 recreationa players	VR matches with AI opponent	No training control	VR improved real table tennis performance
Drew et al., 2020	USA	Darts	Novice players	VR dart throwing, multiple sessions	Real-world training	Improved learning but negative transfer to real darts
Hoffmann et al., 2014	France	Rowing	15 trained rowers	VR pacing/energy-management during 2000 m ergometer	Standard ergometer training	Improved energy management; faster 2000 m performance

Bedir & Erhan, 2020	Turkey	Target sports (archery, etc.)	Target-sport athletes	VR-assisted imagery training	Control	Improved imagery skills and sport performance
Harris et al., 2020	UK	Sport-like aiming task	Adult participants	VR environment, repeated trials	—	VR influenced gaze behavior and motor skill learning

* VR = Virtual Reality; AI = Artificial Intelligence; HMD = Head-Mounted Display; RCT = Randomized Controlled Trial; 3D-MOT = Three-Dimensional Multiple Object Tracking; DM = Decision-Making; OBP = On-Base Percentage; RT = Reaction Time; NR = Not Reported; min = minutes; wk = weeks; n = number of participants.

Table 1 presents the characteristics of the 14 experimental studies included in this review. All studies employed VR, AI, or hybrid VR-based interventions with athlete samples across different sports (e.g., baseball, basketball, soccer, karate, rowing, target sports). Intervention duration ranged from short-term programs (e.g., 3–4 sessions) to longer-term interventions lasting up to 8 weeks. Comparator conditions varied, including traditional practice, video-based training, or no-training controls. The main outcomes assessed were perceptual– motor performance (e.g., decision-making, visual search), motor performance (e.g., batting, heading, dart throwing), and psychological variables (e.g., self-efficacy, imagery skills). Across studies, VR interventions generally showed positive effects on skill acquisition and transfer to real performance, although some results were mixed (e.g., Harenberg et al., 2022; Drew et al., 2020). Three studies reported improvements in perceptual–motor integration following hybrid AI+VR interventions, primarily in team sports such as football and basketball.

Table 2. Methodological quality assessment of the included studies

Author(s), Year	Design	Assessment Tool	Risk of Bias / Quality Level
Gray (2017)	RCT	Cochrane RoB 2.0	Low risk
Panchuk, Klusemann, & Hadlow (2018)	Quasi-experimental	JBI checklist	Moderate risk
Pagé, Bernier, & Trempe (2019)	Quasi-experimental	JBI checklist	Moderate risk
Fortes et al. (2021)	RCT	Cochrane RoB 2.0	Low risk
Harenberg et al. (2022)	RCT	Cochrane RoB 2.0	High risk
Romeas, Chaumillon, Labbé, & Faubert (2019)	RCT	Cochrane RoB 2.0	Moderate risk
Marshall, Uiga, Parr, & Wood (2023)	Quasi-experimental	JBI checklist	Low risk
Petri et al. (2019)	Quasi-experimental	JBI checklist	Moderate risk
Pastel, Petri, & Chen (2023)	Quasi-experimental	JBI checklist	High risk
Michalski, Szpak, & Loetscher (2019)	Quasi-experimental	JBI checklist	Low risk
Drew et al. (2020)	RCT	Cochrane RoB 2.0	Moderate risk
Hoffmann, Filippeschi, Ruffaldi, & Bardy (2014)	RCT	Cochrane RoB 2.0	Low risk
Bedir & Erhan (2020)	Quasi-experimental	JBI checklist	Moderate risk
Harris, Buckingham, Wilson, & Vine (2020)	Quasi-experimental	JBI checklist	High risk

* Randomized Controlled Trial; JBI = Joanna Briggs Institute; RoB = Risk of Bias. Assessment followed Cochrane RoB 2.0 for randomized controlled trials and the JBI checklist for quasi-experimental studies. Low risk = low risk of bias; Moderate risk = some concerns; High risk = high risk of bias.

Table 2 summarizes the methodological quality assessment of the 14 included studies. Randomized controlled trials (n = 5) were evaluated using the Cochrane RoB 2.0 tool, while quasi-experimental designs (n = 9) were assessed with the JBI checklist. Overall, five studies were rated as low risk of bias, six as moderate risk, and three as high risk. The inter-rater agreement between the two reviewers was substantial (Cohen's κ = 0.81), indicating consistency in the quality evaluation process.

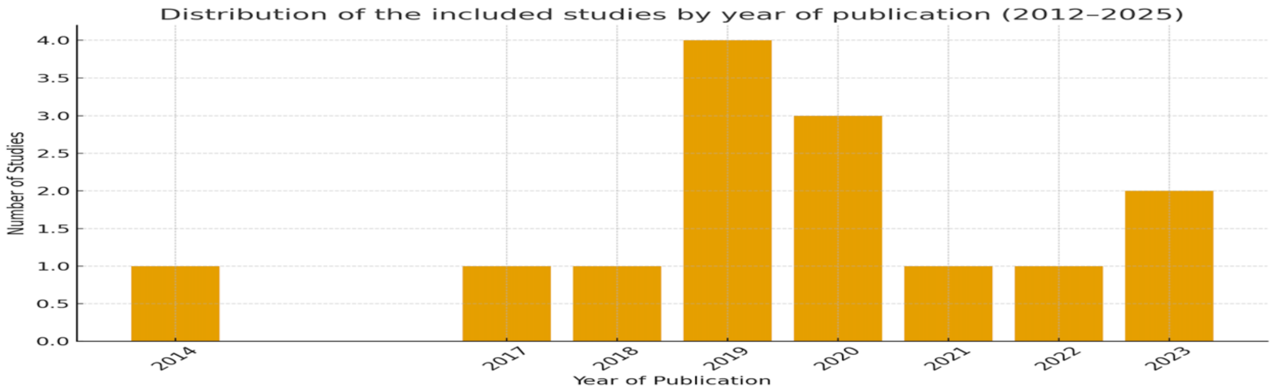

Figure 2. Distribution of the included studies by year of publication (2012–2025)

Figure 2 illustrates the distribution of the included studies by year of publication between 2012 and 2025. As shown, the earliest intervention study was published in 2014, while the number of studies gradually increased from 2017 onwards, reaching a peak in 2019 and maintaining steady growth through 2023. This temporal pattern indicates a growing research interest in the application of VR- and AI-based interventions in sports sciences, particularly in the last five years. The upward trend also reflects the broader technological advances in immersive devices and artificial intelligence algorithms that have facilitated the integration of these tools into athlete training and performance research.

DISCUSSION AND CONCLUSION

(VR), artificial intelligence (AI), and hybrid AI+VR interventions on athletes' skill acquisition and perceptual–motor performance. The overall pattern of results suggests that VR applications are particularly effective in improving reaction time, decision-making accuracy, and balance, while AI-driven adaptive training programs mainly enhance learning efficiency and error reduction. The limited evidence currently available points to potential advantages of hybrid AI+VR approaches, particularly in relation to sport-specific transfer outcomes. These findings are broadly consistent with earlier claims regarding the potential value of immersive technologies in sports training (Neumann et al., 2017) and further highlight the possible role of AI-based adaptive feedback systems in this context.

The integration of VR into sports science reflects its capacity to provide ecologically valid simulations that mimic the perceptual demands and temporal constraints of real competition. By replicating match-like conditions in a controlled and safe environment, VR enhances perception–action coupling and improves the athlete's ability to anticipate and respond effectively. Improvements in postural control and balance observed in several studies further suggest that VR contributes not only to cognitive decision-making but also to fundamental sensorimotor processes. This supports theoretical perspectives from ecological dynamics, which posit that learning is strengthened when practice environments are representative of real-world constraints (Davids et al., 2015).

AI-based interventions, in contrast, demonstrated their primary strength in providing individualized, real-time feedback. By analyzing athletes' movement patterns and error trajectories, AI algorithms dynamically adjusted training tasks to maintain an optimal level of challenge, consistent with the challenge point framework (Guadagnoli & Lee, 2004) and schema theory (Schmidt & Lee, 2019). These adaptive features appear to accelerate motor learning by ensuring that athletes practice at difficulty levels that are demanding but not overwhelming, thereby maximizing both skill retention and transfer. The reviewed studies also suggest that AI interventions may have long-term utility for monitoring workload and preventing injury, although such outcomes have yet to be systematically studied.

Hybrid interventions, which combine the immersive qualities of VR with the adaptive intelligence of AI, produced the most consistent and substantial benefits.These systems simultaneously provide realistic, game-like contexts and individualized progression pathways, enabling athletes to experience both ecological validity and personalization in training. This convergence reflects the principles of deliberate practice theory (Ericsson, 2008), whereby structured and feedback-driven training is considered essential for expertise development. Evidence from hybrid studies showed that perceptual–motor integration and transfer to competitive performance were more robust than with either VR or AI alone.

Moreover, the heterogeneity of sports, intervention protocols, and outcome measures prevented quantative synthesis through meta-analysis, highlightinf the necessity of standardized approaches to study design and reporting. Risk of bias assessments revealed that while six studies demonstrated low risk, five were of moderate and three of high risk, with common shortcomings including lack of blinding and incomplete randomization. Another underdeveloped dimension of this literature is the examination of psychosocial outcomes. While a handful of studies reported improvements in self-efficacy and motivation, most research focused solely on motor performance indicators. This omission is notable given the established role of psychological factors in sustaining engagement and supporting skill acquisition (Deci & Ryan, 2000). Future research would benefit from systematically integrating psychosocial measures to provide a more holistic understanding of how VR and AI influence athlete development. Taken together, the evidence synthesized in this review highlights the significant promise of immersive and intelligent technologies for advancing motor learning and perceptual–cognitive performance in athletes. However, realizing this potential requires more rigorous methodological designs, longer intervention durations, and standardized metrics. Furthermore, future studies should consider incorporating physiological and neurocognitive markers, such as heart rate variability, EEG activity, or eye-tracking, to better clarify the mechanisms through which AI and VR enhance per-formance. Multidisciplinary collaboration between sport scientists, computer engineers, and psychologists will be critical in pushing this field beyond proof-of-concept and into applied, evidence-based practice. This systematic review synthesized evidence from fourteen experimental studies investigating the role of artificial intelligence (AI), virtual reality (VR), and hybrid AI+VR interventions in enhancing skill acquisition and perceptual–motor performance among athletes. The overall findings indicate that VR is particularly effective for improving reaction time, decision-making, and balance, AI-driven adaptive training accelerates learning and reduces errors, and hybrid approaches yield the strongest sport-specific transfer effects. Despite these promising results, methodological limitations such as small sample sizes, short intervention periods, and heterogeneous designs highlight the need for caution when interpreting current evidence. Future research should prioritize larger randomized controlled trials, standardized protocols, and the inclusion of psychosocial and physiological measures to provide a more comprehensive understanding of how immersive and intelligent technologies impact athlete development. Collectively, the findings suggest that AI- and VR-based interventions hold considerable potential for advancing training methodologies in sports science, but further rigorous evidence is required before widespread implementation.

FUTURE STUDIES

Although the current body of literature demonstrates promising evidence for the effectiveness of VR- and AI-based interventions in enhancing perceptual–cognitive and motor skills in athletes, several important avenues remain for future research. First, most existing studies employed relatively small sample sizes, short-term interventions, and limited follow-up assessments. Future research should therefore adopt larger randomized controlled trials, with longitudinal designs, to examine the long-term sustainability and transferability of training effects.

Second, the integration of AI-driven adaptive systems represents an underexplored but highly relevant direction. Adaptive algorithms can personalize task difficulty based on real-time performance metrics (e.g., reaction time, accuracy, physiological load), potentially maximizing training efficiency. Research should test whether such adaptive VR/AI interventions outperform conventional “one-size-fits-all” protocols.

Third, future studies should go beyond traditional motor and decision-making outcomes by systematically incorporating psychological and affective variables, such as motivation, self-efficacy, flow, or competitive anxiety. Such multidimensional approaches would provide a more holistic understanding of how immersive technologies impact athlete development and resilience.

Fourth, there is a need to diversify both sports disciplines and athlete populations. The majority of current research is clustered around soccer, basketball, and baseball. Expanding to endurance sports, combat sports, and skill-based disciplines (e.g., gymnastics, archery, swimming) would strengthen generalizability. Similarly, including youth, female athletes, and elite professionals can highlight whether VR/AI interventions are equally effective across demographics.

Finally, future investigations should explore ecological validity and field-based applications. While laboratory settings dominate current studies, transferring interventions to realistic training environments, combined with wearable sensors and biofeedback, could bridge the gap between experimental findings and real-world sport practice. In this regard, interdisciplinary collaboration between sport scientists, computer engineers, and psychologists will be essential for designing robust, scalable, and impactful VR/AI training programs.

Author Contributions

All aspects of the study—including conceptualization, methodology, software, validation, formal analysis, investigation, data curation, writing (original draft, review, and editing), visualization, and supervision—were carried out solely by A.R.A., who has read and approved the final version of the manuscript.

Funding

No financial support was received from institutions and/or institutions during the preparation and writing of this study.

Institutional Review Board Statement

Since the study is a review, there was no need to obtain ethics committee approval.

Informed Consent Statement

This study is a review in nature, and since it does not involve direct data collection from human participants, informed consent was not required.

Data Availability Statement

Datasets are available through the corresponding author upon reason-able request.

Acknowledgments

No contribution and/or support was received during the writing process of this study.

Conflicts of Interest

The author unequivocally assert that this research was undertaken while devoid of any commercial or financial affiliations that might be perceived as potential conflicts of interest.

REFERENCES

Bedir, E., & Erhan, S. E. (2020). The effect of virtual reality technology on the imagery skills and performance of target-based sports athletes. *Frontiers in Psychology, 11*, Article 2073. https://doi.org/10.3389/fpsyg.2020.02073

Bideau, B., Kulpa, R., Vignais, N., Brault, S., Multon, F., & Craig, C. (2010). Using virtual reality to analyze sports performance. *IEEE Computer Graphics and Applications, 30*(2), 14–21. https://doi.org/10.1109/MCG.2010.10

Bridgeman, J., & Giraldez-Hayes, A. (2023). Using artificial intelligence-enhanced video feedback for reflective practice in coach development: Benefits and potential drawbacks. *Coaching: An International Journal of Theory, Research and Practice, 17*(1), 32–49. https://doi.org/10.1080/17521882.2023.2228416

Davids, K., Araújo, D., Seifert, L., & Orth, D. (2015). Expert performance in sport: An ecological dynamics perspective. In J. Baker & D. Farrow (Eds.), *Routledge handbook of sport expertise* (pp. 273–303). Routledge.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Drew, S. A., Awad, M. F., Armendariz, J. A., Gabay, B., Lachica, I. J., & Hinkel-Lipsker, J. W. (2020). The trade-off of virtual reality training for dart throwing: A facilitation of perceptual-motor learning with a detriment to performance. *Frontiers in Sports and Active Living, 2*, Article 59. https://doi.org/10.3389/fspor.2020.00059

Ericsson, K. A. (2008). Deliberate practice and acquisition of expert performance: A general overview. *Academic Emergency Medicine, 15*(11), 988–994. https://doi.org/10.1111/j.1553-2712.2008.00227.x

Faure, C., Limballe, A., Bideau, B., & Kulpa, R. (2020). Virtual reality to assess and train team ball sports performance: A scoping review. *Journal of Sports Sciences, 38*(18), 192–205. https://doi.org/10.1080/02640414.2019.1689807

Fortes, L. S., Almeida, S. S., Praça, G. M., Nascimento-Júnior, J. R. A., Lima-Junior, D., Barbosa, B. T., & Ferreira, M. E. C. (2021). Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes. *Human Movement Science, 79*, Article 102856. https://doi.org/10.1016/j.humov.2021.102856

Chaimani, A., Caldwell, D. M., Li, T., Higgins, J. P. T., & Salanti, G. (2019). Undertaking network meta-analyses. In J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, & V. A. Welch (Eds.), *Cochrane handbook for systematic reviews of interventions* (Chap. 11). https://doi.org/10.1002/9781119536604.ch11

Gray, R. (2017). Transfer of training from virtual to real baseball batting. *Frontiers in Psychology, 8*, Article 2183. https://doi.org/10.3389/fpsyg.2017.02183

Guadagnoli, M. A., & Lee, T. D. (2004). Challenge point: A framework for conceptualizing the effects of various practice conditions in motor learning. *Journal of Motor Behavior, 36*(2), 212–224. https://doi.org/10.3200/JMBR.36.2.212-224

Harenberg, S., McCarver, Z., Worley, J., Murr, D., Vosloo, J., Kakar, R. S., McCaffrey, R., Dorsch, K., & Höner, O. (2022). The effectiveness of 3D multiple object tracking training on decision-making in soccer. *Science and Medicine in Football, 6*(3), 355–362. https://doi.org/10.1080/24733938.2021.1965201

Harris, D. J., Buckingham, G., Wilson, M. R., Brookes, J., Mushtaq, F., Mon-Williams, M., & Vine, S. J. (2020). The effect of a virtual reality environment on gaze behaviour and motor skill learning. *Psychology of Sport and Exercise, 50*, Article 101721. https://doi.org/10.1016/j.psychsport.2020.101721

Hoffmann, C. P., Filippeschi, A., Ruffaldi, E., & Bardy, B. G. (2014). Energy management using virtual reality improves 2000-m rowing performance. *Journal of Sports Sciences, 32*(6), 501–509. https://doi.org/10.1080/02640414.2013.835435

Joanna Briggs Institute. (2020). *JBI critical appraisal tools*. https://jbi.global/critical-appraisal-tools

Le Noury, P., Polman, R., Maloney, M., & Gorman, A. (2022). A narrative review of the current state of extended reality technology and how it can be utilised in sport. *Sports Medicine, 52*, 1473–1489. https://doi.org/10.1007/s40279-022-01669-0

Marshall, B., Uiga, L., Parr, J. V. V., & Wood, G. (2023). A preliminary investigation into the efficacy of training soccer heading in immersive virtual reality. *Virtual Reality, 27*, 2397–2404. https://doi.org/10.1007/s10055-023-00807-x

Mateus, N., Sousa, V., & Santos, P. (2024). Empowering the sports scientist with artificial intelligence—A scoping review. *Sports, 12*(11), Article 217. https://doi.org/10.3390/sports12110217

Michalski, S. C., Szpak, A., Saredakis, D., Ross, T. J., Billinghurst, M., & Loetscher, T. (2019). Getting your game on: Using virtual reality to improve real table tennis skills. *PLOS ONE, 14*(9), e0222351. https://doi.org/10.1371/journal.pone.0222351

Naik, B. T., Hashmi, M. F., & Bokde, N. D. (2022). A comprehensive review of computer vision in sports: Open issues, future trends and research directions. *Applied Sciences, 12*(9), Article 4429. https://doi.org/10.3390/app12094429

Neumann, D. L., Moffitt, R. L., Thomas, P. R., Loveday, K., Watling, D. P., Lombard, C. L., Antonova, S., & Tremeer, M. A. (2017). A systematic review of the application of interactive virtual reality to sport. *Virtual Reality, 22*(3), 183–198.https://doi.org/10.1007/s10055-017-0320-5

Pagé, C., Bernier, P.-M., & Trempe, M. (2019).Using video simulations and virtual reality to improve decision-making skills in basketball. Journal of Sports Sciences, 37(21), 2403–2410. https://doi.org/10.1080/02640414.2019.1638193

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... McGuinness, L. A. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

Panchuk, D., Klusemann, M. J., & Hadlow, S. M. (2018). Exploring the effectiveness of immersive video for training decision-making capability in elite, youth basketball players. *Frontiers in Psychology, 9*, Article 2315. https://doi.org/10.3389/fpsyg.2018.02315

Pastel, S., Petri, K., & Chen, C.-H. (2023). Training in virtual reality enables learning of a complex sports movement.m *Virtual Reality, 27*(2), 523–540. https://doi.org/10.1007/s10055-022-00679-7

Petri, K., Emmermacher, P., Danneberg, M., Masik, S., Eckardt, F., Weichelt, S., Bandow, N., & Witte, K. (2019). Training using virtual reality improves response behavior in karate kumite. *Sports Engineering, 22*, Article 2. https://doi.org/10.1007/s12283-019-0299-0

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport & Exercise Psychology, 33*(1), 146–155. https://doi.org/10.1123/jsep.33.1.146

Renshaw, I., & Chow, J. Y. (2019). A constraints-led approach to sport and physical education pedagogy. *Physical Education and Sport Pedagogy, 24*(2), 103–116. https://doi.org/10.1080/17408989.2018.1552676

Romeas, T., Chaumillon, R., Labbé, D., & Faubert, J. (2019). Combining 3D-MOT with sport decision-making for perceptual-cognitive training in virtual reality. *Perceptual and Motor Skills, 126*(5), 922–948. https://doi.org/10.1177/0031512519860286

Rothschild, J. A., Stewart, T., Kilding, A. E., & Plews, D. J. (2024). Predicting daily recovery during long-term endurance training using machine learning analysis. *European Journal of Applied Physiology, 124*(11), 3279–3290.

Schmidt, R. A., & Lee, T. D. (2019). *Motor control and learning: A behavioral emphasis* (7th ed.). Human Kinetics.