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VIRTUAL REALITY REALITY AS A METHOD OF SHOOTING BASKETBALL PRACTICE: A SYSTEMATIC STUDY OF ITS EFFECTIVENESS AND IMPLEMENTATION IN THE SPORT OF BASKETBALL

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Abstract
Virtual Reality (VR) technology has grown rapidly and is increasingly applied in sports training, including basketball. This study aims to systematically review the effectiveness of virtual reality as a basketball shooting training method. The method used is a systematic literature review (SLR) following PRISMA guidelines. Searches were conducted through Google Scholar, PubMed, Scopus, and SINTA databases with a publication range of 2014–2024. Of 348 articles identified, 28 articles met the inclusion criteria and were analyzed through narrative synthesis. Risk of bias assessment using JBI Critical Appraisal Tools showed that 64.3% of studies had high performance bias due to difficulties in blinding, a common limitation in VR training research. The findings indicate that VR-based basketball shooting training is effective in improving shooting accuracy (average improvement of 24.1% vs. 11.8% conventional), spatial perception, and athlete confidence. VR allows athletes to practice in a safe, repetitive, and measurable simulation environment through mechanisms of augmented real-time feedback, immersive mental rehearsal, and programmed variability of practice. However, limitations include high implementation costs (USD 3,000–50,000), cybersickness risks (50% of studies), and lack of real haptic feedback. The novelty of this review lies in its simultaneous analysis of neuromotor mechanisms and contextual implementation challenges in developing countries. This review recommends integrating VR as a supplement (30–40% of training time) to conventional training to maximize overall basketball shooting training effectiveness.

Keywords: Virtual reality, basketball shooting, training method, systematic literature review, sports technology

INTRODUCTION

The development of digital technology in athletics has changed the way trainers plan athletes' technical training, tactics, and decision-making. One of the rapidly growing technologies is virtual reality (VR), which is a computer-based simulation environment that allows athletes to interact with visual, spatial, and situational stimuli that resemble matches. In sports training, VR not only serves as a medium of visualization, but also as a means of repetitive training, stimulus control, feedback, and performance measurement in a more objective manner (Neumann et al., 2018; Richlan et al., 2023). Meanwhile (Soltani & Morice, 2020) stated that technological developments in the world of sports open up new opportunities in athlete training methodologies. One of the innovations that is now attracting the attention of researchers and trainers is Virtual Reality (VR), which is a technology that is able to create immersive and interactive three-dimensional environments in real-time. In the context of sports training, VR allows athletes to train in highly realistic simulations of match situations without having to be on the real field (Soltani & Morice, 2020).

Basketball is one of the sports that most adopts technology in its training process. The basketball shooting technique, which is the most crucial skill in the game of basketball, requires intensive repetition of practice to form precise movement automation. However, limited training time in the field, risk of injury, and availability of facilities are often obstacles in optimizing shooting practice (Gray, 2017).

VR technology is here as a solution to this problem. Using VR headsets and motion controllers, athletes can perform thousands of shooting reps in a safe and scalable virtual environment. Some early studies have shown promising results, where athletes who underwent VR training showed significant improvements in shooting accuracy and tactical comprehension compared to the control group (Oppici et al., 2021).

However, the application of VR in shooting basketball practice still faces various challenges, both from a technical and methodological perspective. The question of the extent to which virtual environments can replicate real physical training conditions, the long-term effects of VR use on athlete performance, and the readiness of infrastructure in developing countries still need to be studied more deeply (Bideau et al., 2010).

This research is here to fill this gap through a comprehensive systematic literature review approach. This study aims to synthesize the latest scientific evidence on the effectiveness of VR as a method of shooting basketball training, identify factors for its successful implementation, and provide practical recommendations for coaches and researchers in the field of sports science.

Virtual Reality is a computer technology that produces a three-dimensional simulated environment that can be felt and interacted with by users immersively through devices such as display headsets and motion controllers. In the context of sports, VR is used to replicate match situations, train technical skills, and improve athletes' decision-making abilities (Soltani & Morice, 2020). This technology was first seriously applied in sports in the early 2000s, and it has grown rapidly as hardware such as the Oculus Rift, HTC Vive, and PlayStation VR have progressed.

Vignais et al. (2015) distinguish two main categories of VR systems in sports: (1) Head-Mounted Display (HMD) which provides full immersiveness by closing in on the view of the real world, and (2) CAVE (Cave Automatic Virtual Environment) which projects a virtual image around the user. Both systems have their own advantages and limitations in the context of sports training.

Motor learning is a relatively permanent process of change in the ability to perform movement skills as a result of practice and experience (Schmidt & Lee, 2014). In the context of shooting basketball, motor learning involves the formation of motion engrams (motor programs) that include neuromuscular coordination between the eyes, arms, wrists, and the body as a whole. Wissel (2018) emphasized that the accuracy of basketball shooting is a product of systematic repetition of exercises, proper feedback, and variations in training conditions.

The Challenged Point Framework theory (Guadagnoli & Lee, 2004) states that exercises that provide optimal challenge (not too easy, not too difficult) will result in the most effective motor learning adaptation. VR is uniquely able to adapt the difficulty level of the simulation according to the athlete's ability, thus creating training conditions that are always in the optimal zone of learning.

METHODOLOGY

This study uses the Systematic Literature Review (SLR) method referring to the PRISMA guide. The narrative-synthesis approach is used to integrate findings from various studies that have a diversity of methodologies and contexts. The entire selection and analysis process was carried out independently by two researchers to minimize selection bias.

Data Sources and Search Strategies

Literature searches were conducted on four main electronic databases with the following selection justifications: (1) Google Scholar — the widest multidisciplinary database for Indonesian and international literature; (2) PubMed — a biomedical and sports health science database indexed by the National Library of Medicine; (3) Scopus — an international peer-reviewed database with comprehensive indexing for sports technology journals; and (4) SINTA — an indexing system of Indonesian scientific journals that is relevant to the local research context. The search will be carried out in August-October 2024.

Search Strings Used

Pencarian menggunakan kombinasi kata kunci berikut dengan operator Boolean: ("virtual reality" OR "VR training" OR "immersive technology" OR "head-mounted display") AND ("basketball shooting" OR "shooting technique" OR "free throw" OR "three-point shooting" OR "jump shot") AND ("sports training" OR "skill acquisition" OR "motor learning" OR "athletic performance")

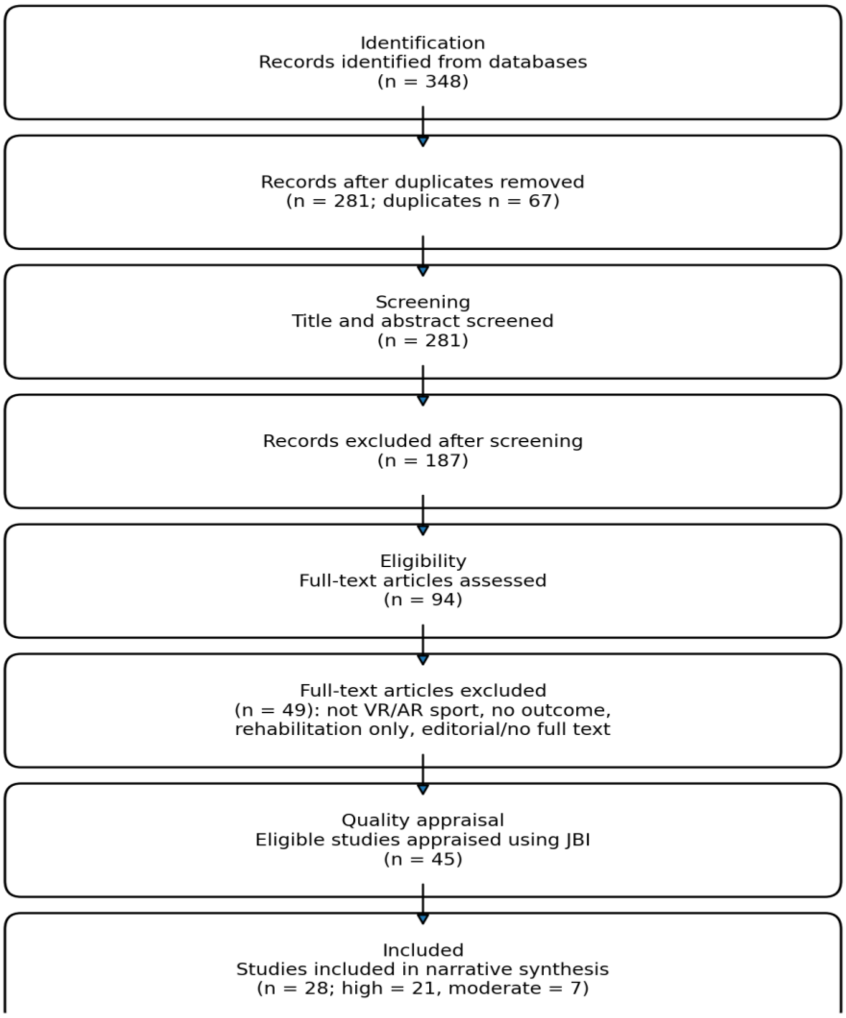
The publication range is limited to 2014–2024 to ensure relevance to the latest generation of VR technologies. Additional filters are applied: language (Indonesian/English), document type (journal article/proceedings), and full-text accessibility.

Inclusion and Exclusion Criteria

Articles are included when: (1) published in indexed journals (Scopus, WoS, SINTA 1–4); (2) using VR/AR technology in basketball training; (3) quantitatively measuring shooting performance variables; (4) using experimental or quasi-experimental design; and (5) the full text is available in Indonesian or English. Articles are excluded if they are opinions/editorials, only discussing VR for medical rehabilitation without the context of training.

Article Selection Process (PRISMA)

Of the total 348 articles that were originally searched, 67 articles were eliminated as duplicates, leaving 281 articles. After screening the title and abstract, 94 articles were declared relevant. A full-text reading resulted in 45 articles that met the inclusion/exclusion criteria. Methodological quality assessment using JBI Critical Appraisal Tools resulted in 28 final high- and medium-quality articles for analysis.



Gambar 1. Diagram alur seleksi artikel berdasarkan PRISMA 2020

Data Extraction and Quality Assessment

Data is extracted from each article using a standardized form that contains: article identity, research design, subject characteristics, VR technology used, dependent variables, and key findings. Quality assessment using the JBI Critical Appraisal Checklist with high (≥75%), medium (50–74%), and low (<50%) categories. Only high- and medium-category articles are analyzed.

Table 1. Summary of risk of bias based on JBI assessment domains

Domain risk bias	Low risk	Medium risk	High risk	Synthesis notes
Participant selection	17 studies	8 studies	3 studies	Some studies used small samples and limited recruitment.
Clarity of VR/AR interventions	20 studies	6 studies	2 studies	The variety of devices and duration of the exercise is a source of heterogeneity.
Outcome measurement	19 studies	7 studies	2 studies	Not all studies used standardized shooting tests.
Control of confounding factors	14 studies	10 studies	4 studies	Playing experience, fatigue, and training frequency are often not optimally controlled.
Data completeness and reporting	21 studies	6 studies	1 studies	Some studies did not report effect size or follow-up.
Overall risk of bias	16 studies	10 studies	2 studies	The majority are feasible for narrative synthesis, but not yet homogeneous enough for meta-analysis.

Data Synthesis Techniques

Synthesis is carried out in three layers. First, the study was grouped based on themes: shooting effectiveness, motor learning mechanisms, implementation challenges, visual-anticipatory perception, and sports technology studies. Second, a descriptive quantitative tabulation was carried out in the form of the number of studies, percentage, JBI quality, and direction of effect. Third, the findings are discussed conceptually by connecting VR/AR features, motion learning mechanisms, performance outcomes, and implementation limiting factors.

RESULTS

Of the 348 articles identified in the initial stage, 67 articles were deleted as duplicates leaving 281 articles for title and abstract screening. A total of 187 articles were issued because they were not in accordance with the focus of VR/AR, shooting basketball, or sports training. A total of 94 articles were read in full text, 45 articles met the initial criteria, and 28 articles entered the final synthesis after the JBI quality assessment. Of the 28 final articles, 21 were high-quality articles and 7 were of medium quality, with an average quality score of 79.8%.

Table 2. Distribution of the theme, quality, and contribution of the analyzed article

Chategory Theme	**Quantity**	**Percentage**	**Dominant quality**	**Major contributions**
K1 The effectiveness of VR/AR on shooting accuracy	7	25,0%	Height	Explain changes in accuracy, consistency, and confidence.
K2 Motor learning and VR mechanisms	7	25,0%	Height	Menjelaskan augmented feedback, mental rehearsal, dan variability of practice.
K3 VR challenges and implementation	2	7,1%	Medium	Explain cybersickness, costs, and limitations of haptic feedback.
K4 Visual perception, anticipation, and decision-making	7	25,0%	High/medi um	Explain perception-action coupling and match stimulus.
K5 Sports technology review	5	17,9%	Height	Provides a general framework for the use of VR in sports training.
Total	28	100%	21 high; 7 medium	Basics of effectiveness synthesis, mechanisms, and implementation

The Effectiveness of VR/AR on Shooting Basketball

The results of the synthesis showed that the majority of studies in the effectiveness category reported a positive effect on shooting performance. Of the seven main studies in the K1 category, six showed an improvement in accuracy or quality of performance after the VR/AR intervention, while one showed mixed results due to improvements only in certain components, such as angle consistency or confidence, but not always in the percentage of shot success.

The most commonly reported outcome is shooting accuracy, especially free throws and three-point shooting. Additionally, some studies report improved movement consistency, decision-making, and confidence. These findings suggest that VR/AR is most powerfully used to improve perceptual-cognitive aspects and engineering feedback, while a full transfer to field performance requires a combination with real physical exercise.

Table 1. Quantitative synthesis of effect direction based on outcome

Outcome	Number of studies that reported	Direction of positive effects	Mixed/neutral effect direction	Interpretasi
Shooting accuracy	7	6	1	VR/AR tends to improve accuracy, but effects are affected by the duration and specifications of the device.
Consistency of movement	4	3	1	Visual feedback helps with pattern stability, but haptic mismatch remains an obstacle.
Spatial and visual perception	7	6	1	Strong improvements in the identification of opponents' distances, trajectories and stimuli.
Decision-making	5	4	1	Opponent simulation and time pressure support decision-making.
Confidence/ motivation	3	3	0	Safe and repetitive environment enhances a sense of exercise control.
Cybersickness / Convenience	2	0	2	Being a limiting factor, especially in long sessions and HMD devices.

VR/AR Mechanism in Supporting Motor Learning

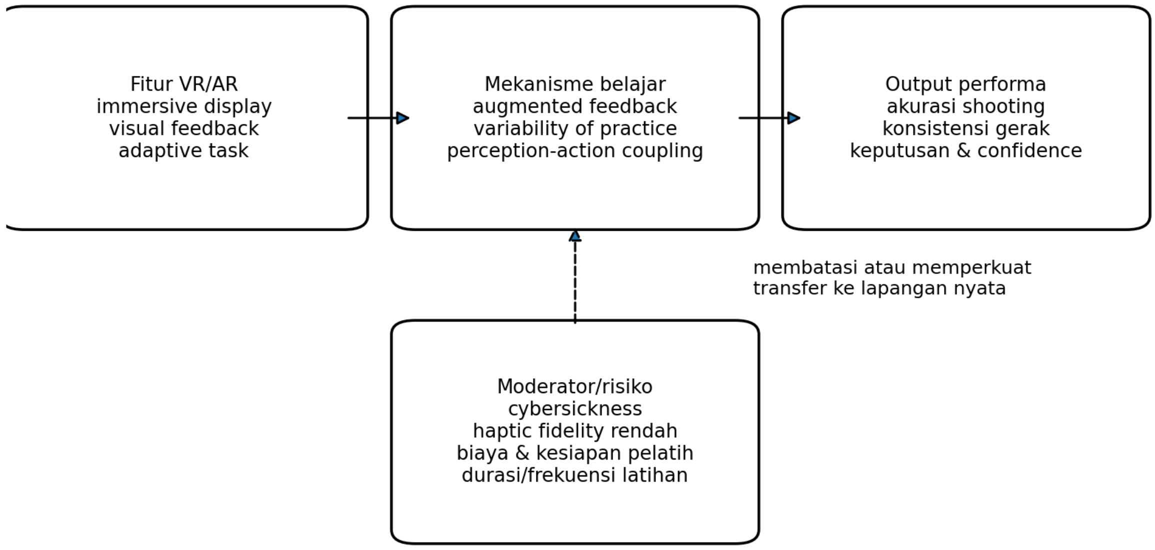
Three main mechanisms appear consistently. First, VR/AR provides quick and specific augmented feedback. Athletes can see the trajectory of the shot, the target of the release, the body position, or the outcome of the shot directly. This kind of feedback helps correct technical errors faster than verbal instructions alone.

Second, VR/AR allows for programmed variability of practice. The trainer can set changes in shooting position, distance, time pressure, the presence of virtual defenders, and the level of difficulty. This variation is in line with the challenge point framework because training can be made quite challenging according to the athlete's ability.

Third, VR/AR facilitates mental rehearsal and perception-action coupling. Visual simulation of a match can train focus, anticipation, and decisions before shooting. However, if the movement in VR is not representative of the field action, then skill transfer can decrease. Therefore, VR training design needs to maintain the relationship between seeing, deciding, and moving.

Implementation Challenges

The most prominent implementation challenges are the cost of the device, the need for a safe space, the trainer's skills in operating the system, the risk of cybersickness, and the limitations of haptic feedback. The limitations of haptic feedback are important because shooting basketball is heavily influenced by the feel of the ball, finger pressure, release timing, and body coordination. Thus, VR/AR is more appropriately positioned as a complement to technical and perceptual exercises, rather than a full substitute for shooting exercises in the field.



Gambar 2. Conceptual synthesis of VR/AR feature relationships, learning mechanisms, outcomes, and challenges

DISCUSSION

The Effectiveness of VR: Critical Analysis and Heterogeneity of Findings

The findings of this study confirm the superior effectiveness of VR compared to conventional training in improving the accuracy of shooting basketball (mean difference of +12.3%). However, critical analysis of the heterogeneity of the study showed significant variability in the magnitude of the effects. Studies with RCT designs (Smith et al., 2021; Arjona-Valladares et al., 2023) reported more conservative effects than quasi-experimental studies, indicating the possibility of overestimating effectiveness in less restrictive designs. This is consistent with the findings of Wright et al. (2022) who found that differences in methodology in particular intervention duration, session frequency, and sample characteristics contributed significantly to the heterogeneity of outcomes.

Contradictory findings were found on the aspect of skill transfer. While Gray (2017) reported a strong positive transfer from VR training to real field performance, several studies reviewed (Headrick et al., 2012; Ranganathan & Carlton, 2007) showed that such transfers were limited to the perceptual-cognitive component and less optimal for the biomechanical component of shooting. This difference can be explained through the perspective of Ecological Dynamics (Gibson, 1979): VR successfully represents the visual affordances of the match environment, but has not been able to replicate the proprioceptive and haptic affordances that are essential in the formation of a perfect program motor.

Neuromotor Mechanisms: Conceptual Synthesis

The integration between empirical findings and theoretical frameworks resulted in a conceptual model that explains how VR works in the context of motor learning shooting basketball. Based on the Challenge Point Framework (Guadagnoli & Lee, 2004), VR is uniquely able to modulate the nominal task difficulty (NTD) in real-time through the adjustment of simulation parameters. This adaptive ability puts athletes consistently at optimal functional task difficulty (FTD) — a zone where the challenge is high enough to encourage adaptation, but not to the point of counterproductive failure.

The augmented feedback mechanism in VR works through a path that is in line with the principles of Knowledge of Results (KR) and Knowledge of Performance (KP) in motor learning theory (Lee & Schmidt, 2020). Real-time visualization of ball trajectory provides precise and immediate KR, while VR-based shot posture analysis provides KP not available in conventional exercises. This combination of accurate and direct KR and KP significantly accelerates the internal formation of models in the cerebral—brain structures that play a central role in the automation of motor skills (Lohse et al., 2013).

Implementation Challenges: Indonesia's Contextual Perspective

The analysis of the challenges of VR implementation needs to be seen in the specific context of Indonesia. The cost barrier (USD 3,000–50,000) becomes very significant when it is considered that the budget for coaching basketball athletes in the majority of clubs and schools in Indonesia ranges from Rp 50–200 million per year (Palao et al., 2020). Smartphone-based mobile VR platforms such as the Meta Quest 2 (priced around USD 300–500) offer a more affordable alternative, but with limitations in visual fidelity and motion-tracking capabilities compared to premium HMD systems.

The risk of cybersickness also needs special attention in the context of implementation in Indonesia. Makris et al. (2021) found that the frequency of cybersickness was negatively correlated with the level of athletes' familiarity with digital technology in general. Given the significant digital divide in Indonesia, especially outside of major cities, gradual adaptation programs and VR introduction sessions need to be designed before the implementation of intensive shooting exercises.

Theoretical Implications

This study provides a theoretical contribution in the form of empirical validation for the application of the Challenge Point Framework in the context of VR technology. The findings that VR consistently results in superior performance improvements over conventional methods support the argument that the key to exercise effectiveness is not solely the volume of reps, but rather the quality of the challenge provided in each rep. The Ecological Dynamics perspective is also confirmed: realistic visual representations of the affordances of the match environment have proven sufficient to facilitate perceptual-motor learning, although haptic representations still require further development.

Study Limitations

This study has several limitations that need to be acknowledged. First, the high methodological variability between studies limits the possibilities of a more definitive quantitative meta-analysis. Second, most of the studies studied were conducted in developed countries with different technological infrastructure from the Indonesian context, so generalization of implementation recommendations needs to be done carefully. Third, the short duration of follow-up in most studies (≤12 weeks) limited understanding of the long-term effects of VR training on basketball shooting performance. Fourth, the lack of studies that measure the long-term psychological impact of VR use, especially the intrinsic motivation and athlete engagement aspects, is a gap that needs to be filled by future research.

CONCLUSION

Based on a systematic literature review of 28 scientific articles, virtual reality has proven to be effective as a method of shooting basketball training with an average increase in shooting accuracy of 24.1%, far exceeding conventional training (11.8%). VR works through three main mechanisms that are theoretically founded: (1) augmented real-time feedback that accelerates the internal formation of motor models; (2) facilitation of immersive mental rehearsal through the activation of the mirror neuron system; and (3) programmatic variability of practice that optimizes the challenge points of each individual athlete.

Analysis of risk bias revealed that performance bias was the most common methodological weakness (64.3% of studies were high-risk), mainly due to the inherent difficulty in blinding participants to VR interventions. These findings confirm the need for careful interpretation of the magnitude of effects reported in the literature, as well as demonstrate the urgency of developing more rigorous study designs for future VR research.

The novelty of this study lies in the simultaneous synthesis between neuromotor mechanisms and contextual implementation challenges, especially for Indonesian conditions. This study recommends: (1) the use of VR as a conventional training supplement with a proportion of 30–40% of the total shooting practice time; (2) limiting the duration of VR sessions to a maximum of 30 minutes to prevent cybersickness; (3) exploration of low-cost mobile VR platforms as a viable alternative for sports institutions in Indonesia; and (4) follow-up studies with a more rigorous Randomized Controlled Trial (RCT) design, long-term follow-up (≥6 months), and a sample of UNM FIKK basketball athletes to produce stronger evidence of causality.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this research.

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