The Open Sports Sciences Journal
DOI: 10.2174/011875399X277947231228071109, 2024, 17, e1875399X277947
ISSN: 1875-399X
1
SYSTEMATIC REVIEW ARTICLE
OPEN ACCESS

Application of Simulation Technology in Football Training: A Systematic Review of Empirical Studies

Teng Jia[1], Jirarat Sitthiworachart[1,*] and John Morris[1]

[1]School of Industrial Education and Technology, King Mongkut's Institute of Technology Ladkrabang, 1 Soi Chalongkrung 1, Ladkrabang, Bangkok 10520, Thailand

Abstract:

Background: This review aimed to cover the characteristics and functions of simulation tools applied to football training, the process and results of empirical research, the benefits of simulation tools for football training, and existing challenges.

Materials and Methods: To investigate and analyze the effect of simulation technology in football training, the PRISMA method was used to systematically review 18 relevant empirical studies published between January, 2014 and July, 2023.

Results: The study identified three types of tools for applying simulation technology to football training, including head-mounted displays, Cave Automatic Virtual Environment (CAVE), and Screen-Based Simulation. These tools have been effective in training football playing techniques (including goalkeeping, heading, *etc.*) as well as football tactical skills (including perception-cognitive and decision-making) and can be used as a supplement to regular training.

Conclusion: If simulation technology is to enhance football training, we suggest that it is necessary to carefully verify the validity of the tool and the long-term impact of simulation training on participants and verify that simulation actually translates to real-world games. At the same time, it is suggested that future research could explore training with mixed VR and AR to develop more realistic and effective training platforms.

Keywords: Simulation, VR, Football training, Screen-based simulation, Cave, Sports.

*Address correspondence to this author at the School of Industrial Education and Technology, King Mongkut's Institute of Technology Ladkrabang, 1 Soi Chalongkrung 1, Ladkrabang, Bangkok 10520, Thailand; E-mail: jirarat.si@kmitl.ac.th

Cite as: Jia T, Sitthiworachart J, Morris J. Application of Simulation Technology in Football Training: A Systematic Review of Empirical Studies. Open Sports Sci J, 2024; 18: e1875399X277947.
http://dx.doi.org/10.2174/011875399X277947231228071109

Received: September 07, 2023
Revised: December 04, 2023
Accepted: December 13, 2023
Published: January 08, 2024

1. INTRODUCTION

1.1. Background

Many facets of human existence have been altered by digital technology and sports, including football. Football training and coaching are crucial to developing player skills and success in the sport. Drills, physical exercises, and tactical discussions are common components of traditional training techniques. However, there is significant interest in introducing virtual reality (VR) technology into football training and instruction to transform the sport. VR provides an immersive and engaging experience that allows players to train in realistic game settings, evaluate their performance, and receive instant feedback. A constructed Virtual Environment (VE) allows participants to interact with 3D computer-produced models in real-time while using their natural senses and talents [1].

In football training, player activities in a sporting environment are usually time-limited, one-of-a-kind, complicated and rely on visual clues gathered from their surroundings [2, 3]. Players' performance is determined by their perception as well as their ability to predict and execute skills under time restrictions [2]. As sport is perceptually demanding, visual-perceptual and visual-motor abilities are frequently emphasized in training programs [4]. Coaches and players desire to enhance these skill sets for competitive performance and to do so, they are embracing new technology to gain an advantage through improved training procedures [5].

Before VR technology was widely used, video-based training (VBT) was a kind of practice in which videos were used to offer stimuli that required participants to make perceptual and cognitive judgments [6, 7]. Approaches included viewing and simulating video sequences of matches [8, 9], obstructing action sequences, and providing participants with feedback on the correctness of test outcomes [10, 11]. VBT allowed learners to practice skills without performing them [12]. It expedited the development of perception-cognitive abilities, especially in sports like football, that call for continuous engagement [13]. Match broadcast video was commonly used in VBT, but it was often criticized for its lack of fidelity [14]. VR was used in training to ensure that training activities represented real scenarios [13, 15]. By enhancing the visual correlation of video simulations, VR improved viewers' immersion [16]. VR has also been recognized as a new VBT technique [17].

1.2. Defining Simulation Technology

Simulations are often computer-based. Using a software-generated model to support managerial and engineering decisions, as well as for training reasons, the models are both visible and interactive. Simulation approaches enhance learning and experimentation. In the conventional understanding, VR is to have a high immersion experience, but currently, it is difficult to widely popularize it with high immersion and high interaction experience in the field of training. Simulation technology has a wider scope and can be widely developed in the field of training; for example, screen-based simulation training is often used in training football and perception-cognitive and decision-making; therefore, we did not choose VR as a theme.

Simulations are inherently ‘virtual’; the objects being simulated are mostly software-generated artefacts. However, we observed a tendency in many published papers to add a ‘virtual’ label to simulations that are clearly already virtual. It was further discovered that some authors recently tried to distinguish between simulations using real objects, for example, games using real players in test scenarios, and supposedly ‘pure’ simulations using entirely synthesized objects, which were labelled ‘Virtual Simulations’. However, simulations using computer modelling to simulate scenarios for multiple purposes have been used for decades and have, logically, considered these simulations to be virtual, without the need for any unnecessary term elevation. Thus, we have followed traditional use and eschewed the addition of ‘virtual’ throughout the paper and simply referred to ‘simulations’.

Simulations have four types [18], which are as follows:

1) Telesimulation: A technique for delivering instruction, training, or evaluation to students at a distant place using telecommunication and simulation resources [19].

2) Cave Automatic Virtual Environment (CAVE) (Immersive): A cube wall construction with projected graphics allows a person to stand inside it to experience an immersive virtual environment. Participants may use special goggles within the CAVE to simulate depth with stereoscopy [20].

3) Extended Reality (Immersive) (XR): A synthesis of all realities, including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), XR creates technology-mediated experiences made possible using a wide range of hardware and software, including sensory interfaces, applications, and infrastructures. XR is referred to as immersive video material, improved media experiences, and interactive and multidimensional human encounters [21] (XRSI.org, X Reality Safety Intelligence).

4) Screen-Based Simulation (Non-Immersive): It is an interactive simulation in which the user interacts with the interface *via* a keyboard, mouse, joystick, or other input device. It is a simulation that is shown on a computer screen with graphical pictures and text, akin to a popular gaming format.

1.3. Literature Review

There have been many reviews on simulation technology-assisted sports training in recent years. Yunchao, Mengyao, and Xingman (2023) systematically reviewed 10 papers published until December, 2022. They systematically reviewed simulation technology used in sports decision training and found that it simulated sports decision-making activities as well as used in assessing and analyzing player decision-making abilities [22]. Further studies demonstrated how useful virtual reality was as a tool for evaluating decision-making. Farley, Spencer, and Baudinet (2019), in their review, noted that VR technology was becoming increasingly used in competitive sports, with an obvious impact on gathering numerous physiological elements, recognizing and strengthening sensorimotor skills, immersing players in competition settings, where response speed was essential, and enhancing skill development [23]. As a result, technological improvements and approaches will have a continuing impact on how coaches focus on building capacities that contribute to the performance of athletes in all sports. Putranto *et al*. (2023) analyzed 30 papers on the implementation of VR technology for sports education and noted that although VR was used to improve individual athlete performance, it worked better as a valuable tool for coaches and teams to design strategies or tactics; they recommended re-evaluating the design of the head-mounted displays to construct head-mounted displays that are lighter in weight, more comfortable, and provide users with broader motor access. They have the potential to increase the use of VR technology in sports teaching and training [24].

Neumann *et al*. (2018) found that a VR-based system for training and participation has several advantages, including allowing athletes to train regardless of weather conditions, providing an opportunity to compete with others in a different geographic area, and allowing precise and repeatable control over the characteristics of the virtual environment [25]. Miles *et al*. (2012) studied virtual environments (VE) for training in ball sports and concluded that improving motor control abilities in ball sports was effective. Anticipation and decision-making abilities could also be trained in a VE, and the task's intensity could be gradually raised. They believed that this field would expand rapidly, with more examples emerging from research laboratories and being adopted by professional sports organizations [1]. Thatcher *et al*. (2020) observed that VR exposed players to components of play that they would not be able to practice easily in a real-world situation, bridging skill gaps and speeding up player improvement. Moreover, academy players could use VR to build and assess decision-making skills. An emerging topic for the study was the potential for VR applications in rehabilitation and recovery [26].

Zhao *et al*. (2022) discussed 10 papers on video-based training (VBT) on anticipation and decision-making in football players. Their summary supported the idea that VBT helped football players by increasing their ability to anticipate and make decisions [27]. They suggested that virtual video and 360 VR were more reliable representations of players' real on-field performance. They further suggested that future studies should consider factors, including weariness, anxiety and off-field noise, that might affect match activity. By including these potential variables that might impact match performance, the realism of a simulated task was assured. Finally, when using VBT, they noted that it was essential to take into account how the training would be applied to on-court performance.

Simulation technologies cover many categories, and there are many studies on simulation technology in sports training, including football. At present, there is no systematic review of the application of simulation technology in football training. Thus, this review presents a critical overview of simulation technology for football training, focusing on the characteristics of simulation technology, experimental process, benefits and challenges of simulation technology. The following research questions guided this review:

1) What were the characteristics of simulation technology?

2) What were the experimental processes?

3) What were the benefits and challenges of simulation technology in football training?

2. MATERIALS AND METHODS

2.1. Search Strategy

We used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology for this review [28]. We searched the following electronic databases: Web of Science, SPORTDiscus, Google Scholar, and Scopus. Our search strategy combined topic, abstract, and keywords. Boolean operations were used for the majority of online searches. The main process for finding appropriate articles follows with some operators adjusted to fit database search expressions:

(“Video-based” OR VR OR Virtual OR Simulation OR Simulator OR “Screen-based” OR Immersive OR CAVE OR 360 OR 3D)

AND

(Football OR Soccer)

AND

(Training OR Coaching OR Teaching OR Playing OR Learning OR Train OR Coach OR Teach OR Play OR Learn OR trainer OR Instructor OR Teacher OR Player OR Learner).

The search language was constrained to research articles in English published between January, 2014 to July, 2023. We analyzed the articles for exclusion or inclusion in two steps: based on the title and abstract and then based on the full article.

2.1.1. Inclusion Criteria

The inclusion criteria were:

(i) Participants were all levels of football players, including beginners,

(ii) The training stimulus or task was created using simulation technologies,

(iii) The paper offered details on samples and experimental procedures, including descriptions of data-collecting methods, experiments, instruments, and measurements.

2.1.2. Exclusion Criteria

The exclusion criteria were:

(i) The simulation tools or tasks were not interactive,

(ii) Not focus on football training or related training evaluation,

(iii) Full-text not available.

2.1.3. Screening Process

Using PRISMA guidelines, we followed four steps in selecting articles (Fig. **1**).

2.2. Overview of the Selected Articles

The basic information of 18 eligible articles, including publication period, characteristics of simulation technology tools, research process (including research design, experimental subjects, and research results), as well as the benefits and challenges of simulation technology for football teaching, are summarized in Tables **1** to **3**. From the perspective of time, although nearly 10 years of papers were searched in this review, the research in this field was concentrated in 2020-2023, with 16 relevant studies since 2020 and only two relevant studies before 2020, which showed that research in this field witnessed strong expansion in the last three years.

Among the 18 selected articles, simulation technology was applied to football training. The purpose of these articles was to conduct virtual training for participants through simulation technology or use simulation technology as a test platform to measure the ability of athletes in some aspects. Most of these articles first designed simulation tools and then conducted empirical research to diagnose and investigate the effect of simulation tools applied to football training. The focus of this systematic review was to study the empirical research process of the selected articles. These 18 articles all included quantitative analysis, and most were completed in a short period of time on a small scale. The participants were mainly professional or semi-professional football players.

It should be noted that the empirical evidence presented in this section is not exhaustive. Despite the fact that we searched the most well-known academic sites for keywords related to simulation technology in football training, the searching and screening processes might have been biased. Other journals and databases may have research works that are relevant. However, our research has been sufficient to comprehend the current research status and challenges associated with the application of simulation technology to football training, and we may provide helpful ideas for future research directions.

3. RESULTS

3.1. What were the Characteristics of Simulation Technology in the Reviewed Studies?

From the classification of simulation tools (Table **1**), of the included studies, nine used Head-Mounted Display (HMD), two used CAVE, and seven used screen-based simulation.

From the description of simulation tools, of the nine studies using HMDs, eight studies used head-mounted displays (HMD), and one used stereoscopic glasses. HMD is a display device that is worn on the head or as part of a helmet and has a small display optic in front of one or both eyes [29]. Fig. (**2**) presents a VR training platform for football. Two studies used CAVE, CAVE is an immersive virtual reality environment where projectors are directed to between three and six of the walls of a room-sized cube (Fig. **3**). For the 360° simulator, seven studies used screen-based simulation; the training content was developed after collecting real football match situations by computer, and the training or testing used a computer screen or video screen.

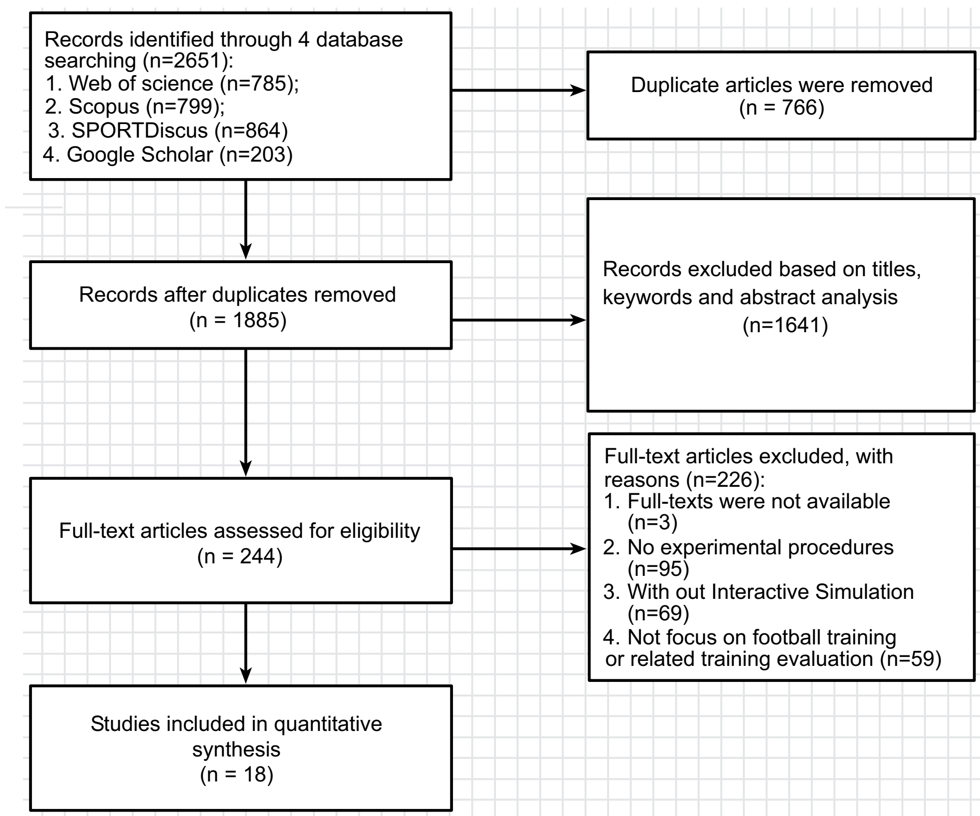

Fig. (1). PRISMA four steps selection.

Table 1. Characteristics of simulation technology.

Simulation Type	Study	Description	Interaction	Function
HMD	[34]	Head-mounted display (HMD), heading virtual ball	Tracking motion capture system	Training soccer heading in VR
	[35]	Donned an HMD and moved their arms and hands to block shots coming toward them	Tracking motion capture system	Training and measuring reaction speed
	[30]	HMD, game modes combine selected game mechanics with specific simulation content	Two gesture-based controllers and a tracking motion capture system	To analyze and train executive functions
	[36]	Through a VR headset, in the VE, jump and try to head the virtual ball	Tracking motion capture system	Evaluate movement variability
	[39]	Users put on HMD determine the best passing option in VE	Tracking motion capture system	Testing visual exploratory activity (VEA)
	[37]	HTC Vive Pro head-mounted display, shooting and passing drills	Tracking motion capture system	Distinguish between skill levels
	[33]	HTC Vive and Rezzil Head Smart application, heading coming from the ball-throwing machine	Tracking motion capture system	Training on heading skills
	[38]	Equipped with stereoscopic glasses and viewed through a rear-projected screen, the goalie moves freely to make the save	Tracking motion capture system	Training goalkeeper
	[40]	Put on a 360 Head Mounted Display (HMD), Watch a selection of football game attack modes	Tracking motion capture system	Testing perceptual-cognitive skills
CAVE	[31]	360° simulator interacts with the projection surface by shooting or passing the ball against the screen	Tracking motion capture system	Training and assessing the cognitive abilities of players
	[32]	Image was projected on a 360◦ screen, and completed the task	Interacted with the screen *via* a hand controller	Investigate in perceptual-cognitive
Screen-based Simulation	[43]	Using computer access to tests in the TacticUP platform	Interact with the computer through the mouse	Testing decision-making skills
	[8]	Using 2D animation simulation tasks of real-world football scenarios	Tap on the screen of the tablet to indicate their responses	To investigate decision-making skills
	[44]	Based on the scene on a high video screen, participants pass the ball to one of three possible targets in reality	By making real passing movements, the assistant records them	Testing decision-making skills
	[45]	A reactivity recognition exercise on a laptop for 1V1 situations in a football match	Interact with video tasks by making handwritten markers	Training decision-making and reactive agility
	[41]	Video-based simulation testing with action prediction interaction *via* buttons	Handheld response devices	Predict the direction of the opponent's attack
	[42]	Respond to each circumstance as fast as possible when the screen gets blocked	Interact through verbal confirmation	Identify intuitive and cognitive processes
	[46]	Football PES 2021 allowed game simulation and group participation	Interact with the game through the gamepad	Develop tactical thinking

Fig. (2). VR training platform for football. Available online under the under the terms of the Creative Commons Attribution License (CC BY) [30].

Fig. (3). 360° simulator. Available online under the Creative Commons Attribution-Non Commercial-NoDerivatives CC-BY-4.0 License [31].

From the interactive characteristics of simulation tools, of the 9 studies using HMDs, virtual reality headsets are HMDs combined with inertial measurement unit (IMU), so the tracking motion capture system is used for real-time feedback on user participation to achieve interaction. Of the 2 studies using CAVE, one of the studies used a tracking motion capture system [31] and another study interacted with the screen *via* a hand controller [32]. Of the 7 studies that used screen-based simulation, participants of four studies interacted directly with the screen *via* sensors (including mouse, tap on the screen, handheld response devices or gamepads) and participants of three interacted orally or in writing.

From the functions of simulation tools, seven studies used the tools for training or assessing player's basic football skills, including training heading [33] [34], measuring reaction speed [35] or executive functions [30], evaluating movement variability [36], and assessing skill levels [37] and goalkeeper [38]. Ten studies used the tools for training or assessing player's perceptual cognition and decision-making, including training and assessing perceptual-cognitive skills [31, 32, 39-42] or training or assessing decision-making skills [8, 43-45]. There was also a very special study that used football PES (2021) as a tool to develop players' tactical thinking [46].

3.2. What were the Experimental Processes in the Reviewed Studies?

A summary of the experimental process is given in Table **2**. All studies were true experimental and quantitative research. Most of the studies used tests to measure the results, a few studies used a combination of tests and questionnaires, and only one study used a questionnaire. A representative study compared experimental and control groups, by pre-test and post-test, to measure heading performance [34]. A representative study analyzed the difference in cognitive ability of different age groups after training intervention [31], and a representative study tested the response of participants to the different intensities of the intervention stimulus [41].

By summarizing the age and gender of participants in the 18 studies, we found that most of the subjects were young players, and no studies compared the performance of males and females. The youngest group was 12-13 years old football players [33].

Comparing the experience levels of the participants with the key findings of the study, we found that in the studies on training or assessing perception-cognitive and decision-making, the experience level of the participants was generally above the professional or semi-professional level, but in the studies of training or assessing motor skills of football, the participants were mostly amateur players.

From the key findings of the studies, we found that simulation technology significantly improved performance. A screen-based simulation was found to be beneficial in improving decision-making skills [41, 45], and the more advanced the athletes were, the better their decision-making skills [8, 44], and this ability improved with age. This made the tool of evaluating the decision-making skills of athletes a reference method for coaches to select talented players [43]. While HMD was more beneficial in enhancing the motor skills of football players, for example, VR training for goalkeepers improved their virtual goalkeeping abilities for a brief period of time [35]. VR training system gave feedback on the skill of the goalkeeper [38], and an experimental group significantly improved their heading performance [34]. Therefore, a VR application can be used as an alternative training for football-specific heading skills [33].

There were two CAVE articles considered in this review, and although the sample size was small, both of them demonstrated the perception-cognition effect of simulation technology in CAVE on football players. The CAVE test can be used for talent identification and the general assessment of cognitive abilities [31]. These results emphasized the importance of perceptual-cognitive skills for talent development and provided information for research and practice in perceptual-cognitive diagnostics in youth soccer [32].

From the key findings, it was also found that, in some studies, participants were surveyed about their emotions and motivation in training. VR training significantly improved perspectives of confidence in general heading ability and raised perceptions of self-efficacy [34]. Gamification had a significant favorable impact on the establishment of interest and motivation to play football [46].

Table 2. Experimental processes.

-	Study	Study Design	Age, Gender Mean ± SD	Experience Level	Key Findings
HMD	[34]	Pre-test; Post-test EG: At least three 30-minute sessions over 10 days CG: Stop heading training within 10 days	EG: Mean age 24, SD = 5. 14 males; 4 females. CG: Mean age 29, SD = 6. 16 males; 2 females	Recreation l level player	EG group significantly improved in the heading and increased confidence and self-efficacy.
	[35]	Pre-test and Post-test. Participants took part in a short-time training in two intensity conditions (EG: fixed intensity; CG: progressive intensity)	Fifty participants between 19 and 39 years of age (12 females, 38 males)	University students and volunteers	VR training for goalkeepers can improve their virtual goalkeeping abilities for a brief period of time.
	[30]	Model construction; participants play the VR game model; Short-term study; Survey through Questionnaire	The age ranged 21-35 (mean age = 24.89 years; SD= 2.99 years) 25 males and 12 females	16 users have experience in playing video games, 21 did not	Results showed that “Hedonic Motivation” and “Effort Expectancy” of participants increased.
	[36]	To compare the variety of movement in specialized and nonspecialized athletes, short time training. Pre-test - VR soccer task - Post-test	44 female soccer athletes (under 16 years old)	30 specialized athletes, 14 nonspecialized athletes	During the soccer header, specialist players had more regular movement patterns than nonspecialized athletes.
	[39]	VR system construction and comparison among groups, each participant was tested for 20 minutes on their visual exploratory activity (VEA)	24 soccer players (7 females,17males, ages 19–30, mean age =23, SD =3).	12 amateurs and 12 beginners	Amateur players have a higher average VEA score than beginners
	[37]	Comparison among groups to examine the construct validity of the VR simulator; 30 minutes per participant	Professional players (13 males, 4 females; M age 28, SD 6). Academy players (14 males, 3 females; M age 14, SD 2). Novice players (9 males, 8 females; mean age 22, SD 4)		The VR platform successfully distinguished participants’ differing skill levels.
	[33]	Instructional design, pre-test, mid-test, and post-test, participants divided into three groups. Each group trained for 8 weeks, twice a week for 50 minutes each time	24 male football players, ages 12 - 13	12-13 years old players	VR application can be used as an alternative training for football-specific heading skills.
	[38]	VR system construction, short time training. Taking the defensive man wall as a variable, analyze the goalkeeper's performance under different variables	11 goalkeepers mean age 26; SD = 4	Mean playing experience 16.4 years (SD = 5.4)	Provide a new method for goalkeeping training and give feedback on goalkeeping.
	[40]	VR and video screen groups, 8-week intervention, comparison among groups	Age: 15–16 (M age = 15.4, SD = 0.3)	National level, experience 5.0 years	Improved decision-making, visual search behavior, and inhibitory control.
Cave	[31]	12-month training period in the virtual 360°. No control group; Pre-test and Post-test	Males: [U12; n = 24, U13; n = 18, U14; n = 18] [U17; n = 22]	Highly talented players of a professional soccer club	The cognitive ability is significantly improved, and the older athletes have better cognitive test results.
	[32]	All participants completed a short time CAVE task, and the computer collected data to evaluate the test results.	292 males, 10 - 23 years old (M age = 15, SD = 3)	10.5-year experience (SD = 3.0)	The perception-cognitive skills of the aged over 16 were significantly higher than younger players.

(Table 2) contd.....

-	Study	Study Design	Age, Gender Mean ± SD	Experience Level	Key Findings
Screen-based simulation	[43]	Comparison among groups to examine the decision-making ability through TacticUP (a short time test of 20 min)	U-14 (selected = 70, deselected = 31), U-15 (selected = 41, deselected = 39); U-16 (selected = 10, deselected = 22), and U-17 (selected =68, deselected = 37) age groups.	Brazilian youth elite male soccer players	The players selected by the Brazilian Youth Elite Football Academy had better decision-making ability in decision time and decision quality than those who were not selected.
	[8]	To assess decision-making, three groups with varying ages and experiences were formed. They had 4 s to make a decision, and upon no response, the software moved to the next clips.	U23 (38 players) U18 (41 players) U16 (39 players)	Premier League Academy Level	The more experienced footballers have better perform in the task.
	[44]	Interventions: 48 testing video situations; each video scene was 5–6 s in duration and had three possible passing options	86 academy players, born 1996 - 2001 (16.7 ± 0.9 years)	In the highest level of German youth league	The tool can distinguish between decision-making skills in a high-achieving young group.
	[45]	6 weeks training. EG has an extra 6 min VBT twice a week	34 male players (EG, n = 18; mean age: 14.4 ±0.4) (CG, n = 16; mean age: 14.4 ±0.5)	A national football academy	It improves the time to make decisions as well as reactive agility, increasing successful decisions.
	[41]	A video-based anticipation task, the reliability of contextual priors as a variable to test players' anticipation. Interventions: Halfway through each trial (after ~2.5 s), the sequence was occluded, and a black screen was displayed	15 female soccer players (M age = 25 years, SD = 4)	Semi-professional and local club-level	Player response was more significant when the context prior was present. Skilled players had a clear prior understanding of the context before the expected action.
	[42]	Players were presented with a representative task on the screen to test how they reacted to the ball	40 males. Mean age = 21, SD= 2)	Professional and semi-professional soccer club players.	The results showed that participants with high creativity had more effective scanning strategies.
	[46]	EG and CG, after 10 months of training to test student tactical thinking skills and motivation	30 male students, 10–12. EG 15 students, CG 15 students	No experience in football training	It helped players better understand football skills and the acquisition of competitive experience.

Table 3. Benefits and challenges of simulation technology in training.

Type of Simulation	Study	Benefits	Challenges
HMD	[34]	Fear reduction in real-world situations	Negative transfer effects may occur if the heading platform is not representative
	[35]	Null	Current results were not replicated in a verified real-world environment
	[30]	Immersive executive function training in a fully virtual environment	Lack of theoretical and empirical support for the offered training tasks
	[36]	Null	Lack of performance measures to evaluate the athlete's attention and perception of the corner kick
	[39]	Null	During body rotation or movement, participants worried that the hardware (cable) affected them
	[37]	Allow injured players to keep their perceptual-cognitive skills	It was not clear that perceptual-cognitive processes in the virtual world were similar to real-world
	[33]	Full immersive systems were more suitable for training, exercise, and sports	Null
	[38]	Simulator was transportable, allowing complete freedom for the immersed player	Null
	[40]	Developed attentional focus	The long-term effects of training are uncertain
Cave	[31]	As an additional training tool for the development of players	Null
	[32]	Allowed players to obtain information through more realistic behavior	Did not reflect the real training and competitive environment

(Table 3) contd.....

Type of Simulation	Study	Benefits	Challenges
Screen-based Simulation	[43]	Promoted football talent identification and selection processes	Null
	[8]	Easily used through a computer	Null
	[44]	Null	Null
	[45]	Supplement to regular football training	The long-term effects are not clear
	[41]	Null	It failed to preserve the functional coupling between perception and action, lack of real-world application
	[42]	Null	It did not reproduce a player's first-person viewing perspective
	[46]	Without time and space constraints, low training risk	Null

3.3. What were the Benefits and Challenges of Simulation Technology in Football Training?

By summarizing the benefits of simulation technology (Table **3**), we found the following benefits for the players: it provided immersive training in a fully virtual environment with no time and space constraints and low training risk [30, 34, 46], it allowed injured players to maintain a level of perceptual-cognitive skill [37], and it was easy to use through a computer [8]. Following are the benefits for coaches: it provides an additional instrument for player scouting and development improvement, promoting talent discovery and selection in football [31, 43]. Moreover, it was a supplement to regular football training [45].

By summarizing the challenges of simulation technology, we found that the long-term effects of training were not clear [40, 45]. The current results were not replicated in a verified real-world environment, as they did not reflect the real training and competitive environment [32, 35]. During body rotation or movement, participants worried that the hardware (cable) affected them [39]. It did not accurately reproduce a first-person perspective [42]. Moreover, there was a lack of theoretical and empirical justification for the included training tasks [30].

4. DISCUSSION

We reviewed 18 empirical studies on simulation technology in football training since 2014 and summarized the characteristics of simulation technology, the process of empirical research, and the benefits and challenges of simulation technology applied in football training. Next, we discussed the application of simulation technology in football training and the limitations and challenges of simulation technology.

4.1. Discuss the Application of Simulation Technology in Football Training

We summarized the following perspectives on the application of simulation technology in football training. The most significant benefits are its ability to generate realistic game scenarios and replicate match conditions, training, and testing in this virtual environment, which brings new training methods to coaches and athletes as a supplement to traditional training. The current studies reported that it allows players to work on specific technical skills in a focused and repetitive manner, and the instant feedback provided by the simulation software allows players to discover areas for improvement and make adjustments that are needed to improve their abilities. Injury prevention and rehabilitation can also benefit from simulation technology. Players can simulate game movements and practice techniques using VR headset displays and motion-capture systems without putting undue strain on their bodies, creating a safer training environment and lowering the risk of injury. Furthermore, simulation technology created scenarios that challenged players to analyze game dynamics, anticipate opponents' moves, and make appropriate decisions. This helps enhance the players' tactical acumen and ability to adapt to different game situations, which challenges their mental abilities, such as perception, attention, and memory, ultimately improving their ability to process information and make quick decisions on the field. Finally, the interactive nature of simulation technology can increase engagement and motivation among football players and the realistic visuals and game-like experience of simulation training can make training sessions more enjoyable and engaging, leading to improved focus and effort from the players.

There has been some discussion about the use of simulation technology in football training in other studies. The VR platform has the potential to be used during the rehabilitation of injured football players who need to maintain a level of perceptual-cognitive skill while avoiding the physical stress experienced in real environments. VR has been shown to increase enjoyment, adherence to rehabilitation exercises, and confidence [47]. A VR digital gaming platform for teaching football skills might be useful during the rehabilitation of injured football players who need to keep their perceptual-cognitive skills while avoiding physical exercise [37]. Virtual technologies may be used to simulate real-life sporting environments, allowing players to play without worry of hurting themselves, recognize the details of each technical behavior, and examine their movements for miniature errors [48]. The advantage of using virtual reality to instruct sports skills is that it gives the user a sense of involvement and is an effective eye-hand coordination training solution that combines perception and action. VR offers an appealing option for a better understanding of the athlete perception-action process [49]. It allows players to practice decision-making in a controlled environment, which improves their understanding of tactical situations and the ability to make quick and effective decisions on the field. It indicates that simulation technology can help football players develop tactical awareness and decision-making skills [27]. Sports video games can be an effective tool for motivating young individuals to engage in real-life sports and physical activity since they have a significant impact on cognitive engagement, affective engagement, behavioral engagement, and accessibility, all of which are strongly linked to real-life sports participation [50].

4.2. Limitations and Challenges of Simulation Technology in Football Training

While simulation technology has been shown to be beneficial in football training, it is not without limitations and challenges. These elements must be taken into account to ensure effective implementation and maximize the potential impact.

Simulation technology allows players to practice technical aspects, such as heading, shooting, and tactics, but it cannot simulate the physical demands and challenges of real-world match scenarios. Football is a contact sport, in which players must show skills while under pressure from opposing players, making it difficult to fully simulate these aspects in a virtual setting. Even if players excel in simulated training, it is unclear how well those skills translate to real-world scenarios. Transferring skills learned in a controlled virtual environment to actual matches can be ineffective because it does not accurately reflect the real training and competitive environment [32]. Even without pressure from the opposing player, simulating the demonstration of a skill or decision while running or jumping is rare in existing research. Therefore, the practice in the virtual environment is not very helpful to professional athletes at present. This is a direction worth studying in the future, and the training environment that combines virtual and reality may better meet the training requirements.

It cannot accurately replicate complex decision-making processes. In order to succeed in football, players must quickly assess a variety of options and react to changing circumstances. Even though they can present some decision-making difficulties, simulations frequently lack the spontaneity and unpredictability of actual match scenarios. This restriction might make it more difficult for players to adjust to a real game’s dynamic nature. Additionally, it lacked practical application and failed to maintain the functional coupling between perception and action [41].

In terms of HMD, it is highly immersive VR. Due to the need for a lengthy cable trailing from the headset to transmit the visual data, HMDs have been claimed to disrupt a user's physical activities. Some are heavy and cumbersome, which may distract the user [51]. It was eventually overtaken by more user-friendly wireless VR headsets. Still, HMD users are unable to see their own hands, requiring the use of an avatar, which might lead to latency concerns [51]. Within such an environment, it is necessary to keep the athlete's constraints to a minimum and provide them the flexibility of movement they would enjoy in such situations. Despite all the advances in virtual reality technology, for example, the reduction of latency in devices, such as HMDs, symptoms of cybersickness can still recur in a wide range of people. As a result, using VR for sports analysis and skill acquisition has its limitations, just like any other training method, and some aspects must be perceived or implemented in a real-world environment.

In terms of screen-based simulation, since it focuses primarily on visual and cognitive processing, it might not accurately mimic the physical demands and muscle memory formation needed in real-match scenarios. The development of motor skills and real-time physical feedback are not adequately addressed by video analysis despite its potential value for tactical learning and understanding of game patterns. Due to the simulator's low immersion level, screen-based simulations may cause attention problems and a lack of first-person perspective [42].

Many studies report difficulties related to exposure time in immersive simulation environments. Although there were no problems caused by prolonged exposure to simulators reported in the studies we selected, this is an aspect worth explanation and consideration. To solve the difficulties related to exposure time in an immersive simulation environment, it is necessary to consider optimizing hardware, control of exposure time, training user adaptability, and individual differences. This can improve the usability and user experience of simulation technology in football training.

4.2.1. Small Sample Size

This study faced limitations in terms of small samples or short study durations. For example, some studies used a relatively small number of participants, which could limit the generalizability of the findings. Additionally, due to the constraints of time and resources, some studies had a relatively short duration, which could limit the capture of long-term effects or fully assess the impact of simulation technology. These limitations highlight the need for future studies to include larger samples and longer durations to provide more robust and comprehensive evidence of the simulation's effectiveness. Simulation techniques are also highly specialized in differentiating players' skill levels, cognition, and decision-making abilities.

4.2.2. Usability

When studying usability involving users, it is necessary to focus on the diversity of users, including different ages, genders, skill levels, and backgrounds. At the same time, it is necessary to develop scientific test plans and methods to ensure the accuracy and reliability of test results. Through usability studies, the effectiveness, safety and usability of virtual simulation technology can be evaluated, and a reference can be provided for further promotion and application.

4.2.3. Youth vs. Professional Players

A limitation of the study was the disregarding of empirical studies on usability, especially on football athletes. This paper contributes little to the training and improvement of professional players but is useful for identifying talented professional players for a team [31, 43]. Tests involving users can also bring important contributions related to the benefits and challenges of technology for football athletes. Future research could translate the success of amateur and young players into professional players, such as decision-making development.

5. FUTURE RESEARCH DIRECTIONS AND RECOMMENDATIONS

It is necessary to take into account the content validity and construct of the VR environment; this suggests that in order to give an in-depth comparison between the effectiveness of conventional training and VR training, the transfer of instructed skills must be assessed and confirmed by effectiveness under real-life situations [52]. It is crucial to assess how effectively training transfers from a simulated environment to a real environment. It is obvious that, in spite of the rapid development of VR sports platforms, the assessment of these simulators was left behind. The effectiveness of sport-related VR training should be extensively investigated before it can be implemented as a realistic and productive supplement to traditional sports training. Greater cooperation is required between those who develop these technologies and those who have the expertise and abilities to independently and deeply test and validate them. Another consideration is the effect on player interaction and team dynamics. Football is a fast-paced sport that requires communication and teamwork. Due to the use of simulation technology, the emphasis may shift toward individual training, limiting real-time interactions between players. Future research must strike the right balance between individual skill development and team collaboration for successful implementation.

More studies are needed to investigate the universality of impacts with simulation technologies. In addition to professional athletes and elite youth athletes, studies should include more diverse populations, children, students, and football novices. There is a need to focus on campus football and amateur football outside the professional football system to promote the popularization of simulation technology in football training. In professional football, there is a need to develop a design that combines simulation technology with training courses to verify the training effect through long-term training.

The nature of computer-based interactions is growing more diversified, with more overlap between various types of technologies and their applications. However, the integration of real-world and virtual environmental elements in sports applications has yet to be extensively studied. Firstly, the integration of VR and AR can enhance tactical training by creating more dynamic and interactive scenarios. VR technology can be used to recreate realistic game situations, allowing players to fully immerse themselves in a virtual football match. AR can then overlay additional information, such as tactical instructions, player movement analysis, or real-time feedback, directly onto the player's field of view. This enables players to make tactical decisions in a realistic environment while having access to crucial information for optimal performance. Exploring the effectiveness of VR-AR integration, or 'mixed reality', in tactical training would be a promising direction.

CONCLUSION

This systematic review highlights the positive effects of simulation technology in improving technical skills, tactical decision-making, and injury prevention. There are three types of tools for applying simulation technology to football training, which significantly improves performance. These tools can be used as a supplement to regular football training. The HMD (immersive VR tool) is mainly used to train players in basic skills, with virtual reality headsets combined with IMU, making a motion tracking system for real-time feedback on user participation to achieve interaction. CAVE and screen-based simulations are mainly used to train and diagnose players' perceptual cognition and decision-making. CAVE interacts with the system through sensing equipment. Screen-based simulation interacts with the screen by using the mouse or key senses.

In conclusion, simulation technology has extensive applications in football training, effectively facilitating tactical training, injury prevention, rehabilitation, and skill development. However, the current limitations and challenges associated with simulation technology must be addressed. Future research should focus on overcoming these limitations to fully unlock the potential benefits of simulation technology in the football domain. With continued advances and research, a balanced approach that combines simulation training with real on-field practice, tactical training and match experience is essential for players to develop a well-rounded ability. Exploring the training environment, combining VR and AR, and promoting a better combination of simulation training and reality is the future development trend.

LIST OF ABBREVIATIONS

VBT	=	Video-based Training
CAVE	=	Cave Automatic Virtual Environment
VR	=	Virtual Reality

CONSENT FOR PUBLICATION

Not applicable.

STANDARDS OF REPORTING

PRISMA guidelines and methodology were followed.

AVAILABILITY OF DATA AND MATERIALS

The data that supporting the findings of this study will be available from corresponding author [J.S.] upon request.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

SUPPLEMENTARY MATERIAL

PRISMA checklist is available as supplementary material on the publisher's website along with the published article.

Supplementary material is available on the publisher's website along with the published article.

REFERENCES

[1] Miles HC, Pop SR, Watt SJ, Lawrence GP, John NW. A review of virtual environments for training in ball sports. Comput Graph 2012; 36(6): 714-26. http://dx.doi.org/10.1016/j.cag.2012.04.007

[2] Craig C. Understanding perception and action in sport: How can virtual reality technology help? Sports Technol 2013; 6(4): 161-9. http://dx.doi.org/10.1080/19346182.2013.855224

[3] Kulpa R, Bideau B, Brault S. Displacements in virtual reality for sports performance analysis. In: Steinicke F, Visell Y, Campos J, Lécuyer A, Eds. Human Walking in Virtual Environments: Perception, Technology, and Applications. New York, NY: Springer 2013; pp. 299-318. http://dx.doi.org/10.1007/978-1-4419-8432-6_13

[4] Appelbaum LG, Erickson G. Sports vision training: A review of the state-of-the-art in digital training techniques. Int Rev Sport Exerc Psychol 2018; 11(1): 160-89. http://dx.doi.org/10.1080/1750984X.2016.1266376

[5] Covaci A, Postelnicu C-C, Panfir AN, Talaba D. A Virtual Reality Simulator for Basketball Free-Throw Skills Development in Technological Innovation for Value Creation in IFIP Advances in Information and Communication Technology. Berlin, Heidelberg: Springer 2012; pp. 105-12. http://dx.doi.org/10.1007/978-3-642-28255-3_12

[6] Hadlow SM, Panchuk D, Mann DL, Portus MR, Abernethy B. Modified perceptual training in sport: A new classification framework. J Sci Med Sport 2018; 21(9): 950-8. http://dx.doi.org/10.1016/j.jsams.2018.01.011 PMID: 29433921

[7] Larkin P, Mesagno C, Spittle M, Berry J. An evaluation of video-based training programs for perceptual-cognitive skill development. A systematic review of current sport-based knowledge. Int J Sport Psychol 2015; 46(6): 555-86.

[8] Farahani J, Soltani P, Rezlescu C, Walsh V. Assessing decision making using 2D animations in elite academy footballers. in Progress in Brain Research,. Elsevier 2020; pp. 71-85. http://dx.doi.org/10.1016/bs.pbr.2020.06.016

[9] Ward P, Williams AM. Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. J Sport Exerc Psychol 2003; 25(1): 93-111. http://dx.doi.org/10.1123/jsep.25.1.93

[10] Gorman AD, Farrow D. Perceptual training using explicit and implicit instructional techniques: Does it benefit skilled performers? Int J Sports Sci Coaching 2009; 4(2): 193-208. http://dx.doi.org/10.1260/174795409788549526

[11] Nelson LJ, Potrac P, Groom R. Receiving video-based feedback in elite ice-hockey: A player's perspective. Sport Educ Soc 2014; 19(1): 19-40. http://dx.doi.org/10.1080/13573322.2011.613925

[12] Larkin P, Mesagno C, Berry J, Spittle M. Development of a valid and reliable video-based decision-making test for Australian football umpires. J Sci Med Sport 2014; 17(5): 552-5. http://dx.doi.org/10.1016/j.jsams.2013.08.001 PMID: 23992660

[13] Pagé C, Bernier PM, Trempe M. Using video simulations and virtual reality to improve decision-making skills in basketball. J Sports Sci 2019; 37(21): 2403-10. http://dx.doi.org/10.1080/02640414.2019.1638193 PMID: 31280685

[14] Broadbent DP, Causer J, Williams AM, Ford PR. Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. Eur J Sport Sci 2015; 15(4): 322-31. http://dx.doi.org/10.1080/17461391.2014.957727 PMID: 25252156

[15] Panchuk D, Klusemann MJ, Hadlow SM. Exploring the effectiveness of immersive video for training decision-making capability in elite, youth basketball players. Front Psychol 2018; 9 http://dx.doi.org/10.3389/fpsyg.2018.02315

[16] Kittel A, Larkin P, Elsworthy N, Lindsay R, Spittle M. Effectiveness of 360° virtual reality and match broadcast video to improve decision-making skill. Science and Medicine in Football 2020; 4(4): 255-62. http://dx.doi.org/10.1080/24733938.2020.1754449

[17] Vignais N, Kulpa R, Brault S, Presse D, Bideau B. Which technology to investigate visual perception in sport: Video *vs*. virtual reality. Hum Mov Sci 2015; 39: 12-26. http://dx.doi.org/10.1016/j.humov.2014.10.006 PMID: 25461430

[18] Verkuyl M, Dubois N, Goldsworthy S, Merwin T, Willet T, Job T. Virtual simulation : An educator's toolkit. 2022. Available from: https://openlibrary-repo.ecampusontario.ca/jspui/handle/123456789/1487 (Accessed: Jul. 07, 2023).

[19] McCoy CE, Sayegh J, Alrabah R, Yarris LM. Telesimulation: An innovative tool for health professions education. AEM Educ Train 2017; 1(2): 132-6. http://dx.doi.org/10.1002/aet2.10015 PMID: 30051023

[20] Ronchi E, Mayorga D, Lovreglio R, Wahlqvist J, Nilsson D. Mobile-powered head-mounted displays *versus* cave automatic virtual environment experiments for evacuation research. Comput Animat Virtual Worlds 2019; 30(6): e1873. http://dx.doi.org/10.1002/cav.1873

[21] XRSI Standard taxonomies for emerging tech ecosystem," X reality safety intelligence. Available from: https://xrsi.org/definitions (Accessed Aug. 18, 2023).

[22] Yunchao M, Mengyao R, Xingman L. Application of virtual simulation technology in sports decision training: A systematic review Front Psychol, 2023. Available from: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1164117 (Accessed: Jul. 07, 2023). http://dx.doi.org/10.3389/fpsyg.2023.1164117

[23] Farley ORL, Spencer K, Baudinet L. Virtual reality in sports coaching, skill acquisition and application to surfing: A review. J Hum Sport Exerc 2019; 15(3) http://dx.doi.org/10.14198/jhse.2020.153.06

[24] Putranto JS, Heriyanto J, Kenny S, Achmad S, Kurniawan A. Implementation of virtual reality technology for sports education and training: Systematic literature review. Procedia Comput Sci 2023; 216: 293-300. http://dx.doi.org/10.1016/j.procs.2022.12.139

[25] Neumann DL, Moffitt RL, Thomas PR, *et al.* A systematic review of the application of interactive virtual reality to sport. Virtual Real 2018; 22(3): 183-98. http://dx.doi.org/10.1007/s10055-017-0320-5

[26] Thatcher B, Ivanov G, Szerovay M, Mills G. Virtual reality technology in football coaching: Barriers and opportunities. Int Sport Coach J 2021; 8(2): 234-43. http://dx.doi.org/10.1123/iscj.2020-0011

[27] Zhao J, Gu Q, Zhao S, Mao J. Effects of video-based training on anticipation and decision-making in football players: A systematic review. Front Hum Neurosci 2022; 16 http://dx.doi.org/10.3389/fnhum.2022.945067

[28] Moher D, Shamseer L, Clarke M, *et al.* Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 2015; 4(1): 1.

http://dx.doi.org/10.1186/2046-4053-4-1 PMID: 25554246

[29] Shibata T. Head mounted display. Displays 2002; 23(1-2): 57-64. http://dx.doi.org/10.1016/S0141-9382(02)00010-0

[30] Krupitzer C, Naber J, stauffert J-P, *et al.* CortexVR: Immersive analysis and training of cognitive executive functions of soccer players using virtual reality and machine learning Front Psychol 2022; 13: 754732. http://dx.doi.org/10.3389/fpsyg.2022.754732

[31] Heilmann F, Weigel P, Wollny R. Analysis of cognitive abilities measured in a laboratory-controlled 360° simulation in soccer. German J Exercise Sport Res 2021; 51(3): 302-11. http://dx.doi.org/10.1007/s12662-021-00713-x

[32] Ehmann P, Beavan A, Spielmann J, *et al.* Perceptual-cognitive performance of youth soccer players in a 360°-environment – Differences between age groups and performance levels. Psychol Sport Exerc 2022; 59: 102120. http://dx.doi.org/10.1016/j.psychsport.2021.102120

[33] Gürbüz E, Taş M. The effect of virtual reality training on heading skills in 12-13 years old child footballers. Spor Bilimleri Araştırmaları Dergisi 2023; 8(1): 43-56. http://dx.doi.org/10.25307/jssr.1172607

[34] Marshall B, Uiga L, Parr JVV, Wood G. A preliminary investigation into the efficacy of training soccer heading in immersive virtual reality. Virtual Real 2023; 27(3): 2397-404. http://dx.doi.org/10.1007/s10055-023-00807-x

[35] Shimi A, Papantoniou A, Neokleous K, Avraamides MN. Athletic performance in immersive virtual reality. European Journal of Psychology Open 2022; 81(1): 24-33. http://dx.doi.org/10.1024/2673-8627/a000021

[36] Riehm CD, Bonnette S, Riley MA, *et al.* Movement regularity differentiates specialized and nonspecialized athletes in a virtual reality soccer header task. J Sport Rehabil 2023; 32(3): 248-55. http://dx.doi.org/10.1123/jsr.2021-0432 PMID: 36265842

[37] Wood G, Wright DJ, Harris D, Pal A, Franklin ZC, Vine SJ. Testing the construct validity of a soccer-specific virtual reality simulator using novice, academy, and professional soccer players. Virtual Real 2021; 25(1): 43-51. http://dx.doi.org/10.1007/s10055-020-00441-x

[38] Brault S, Kulpa R, Duliscouët L, Marin A, Bideau B. Virtual kicker *vs.* real goalkeeper in soccer: a way to explore goalkeeper's performance. Mov Sport Sci 2015; 89: 79. http://dx.doi.org/10.3917/sm.089.0079

[39] Rojas Ferrer CD, Shishido H, Kitahara I, Kameda Y. Read-the-game: System for skill-based visual exploratory activity assessment with a full body virtual reality soccer simulation. PLoS One 2020; 15(3): e0230042. http://dx.doi.org/10.1371/journal.pone.0230042 PMID: 32182621

[40] Fortes LS, Almeida SS, Praça GM, *et al.* Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes. Hum Mov Sci 2021; 79: 102856. http://dx.doi.org/10.1016/j.humov.2021.102856 PMID: 34391110

[41] Gredin NV, Bishop DT, Williams AM, Broadbent DP. Integrating explicit contextual priors and kinematic information during anticipation. J Sports Sci 2021; 39(7): 783-91. http://dx.doi.org/10.1080/02640414.2020.1845494 PMID: 33320053

[42] Roca A, Ford PR, Memmert D. Perceptual-cognitive processes underlying creative expert performance in soccer. Psychol Res 2021; 85(3): 1146-55. http://dx.doi.org/10.1007/s00426-020-01320-5 PMID: 32200407

[43] Machado G, González-Víllora S, Teoldo I. Selected soccer players are quicker and better decision-makers in elite Brazilian youth academies. Int J Perform Anal Sport 2023; 23(2): 65-82. http://dx.doi.org/10.1080/24748668.2023.2181609

[44] Murr D, Larkin P, Höner O. Decision-making skills of high-performance youth soccer players. German Journal of Exercise and Sport Research 2021; 51(1): 102-11. http://dx.doi.org/10.1007/s12662-020-00687-2

[45] Nimmerichter A, Weber N, Wirth K, Haller A. Effects of video-based visual training on decision-making and reactive agility in adolescent football players. Sports 2015; 4(1): 1. http://dx.doi.org/10.3390/sports4010001 PMID: 29910249

[46] Zhang C. Raising student motivation and interest in football through rich media platforms: The experience of China. Interact Learn Environ 2022; 1-13. http://dx.doi.org/10.1080/10494820.2022.2091613

[47] Sveistrup H. Motor rehabilitation using virtual reality. J Neuroeng Rehabil 2004; 1(1): 10. http://dx.doi.org/10.1186/1743-0003-1-10 PMID: 15679945

[48] Yan H. Construction and application of virtual reality-based sports rehabilitation training program. Occup Ther Int 2022; 2022: 1-13. http://dx.doi.org/10.1155/2022/4364360 PMID: 35611341

[49] Tyack A, Mekler ED. Off-Peak: An examination of ordinary player experience. Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. 1-12. http://dx.doi.org/10.1145/3411764.3445230

[50] Bandara K, Pemarathna R. Impact of sports-themed video games playing on real- life sports involvement of undergraduates in rajarata university of sri lanka 2019. Available from : https://www.researchgate.net/publication/333974130_IMPACT_OF_SPORTS-THEMED_VIDEO_GAMES_PLAYING_ON_REAL-_LIFE_SPORTS_INVOLVEMENT_OF_UNDERGRADUATES_IN_RAJARATA_UNIVERSITY_OF_SRI_LANKA

[51] Miles HC, Pop SR, Watt SJ, *et al.* Investigation of a virtual environment for rugby skills training. 2013 International Conference on Cyberworlds. 56-63. http://dx.doi.org/10.1109/CW.2013.45

[52] John NW. Design and implementation of medical training simulators. Virtual Real 2008; 12(4): 269-79. http://dx.doi.org/10.1007/s10055-008-0101-2