



Evaluation of virtual reality as a tool for improving basketball players' individual skills and movement

Grigoris Masadis, Maria Giannousi, Charalampos Liakos

Department of Physical Education and Sports Science, Democritus University of Thrace, University Campus, Komotini, Greece

Abstract

The purpose of this study was to explore the assessment of virtual reality (VR) through a review of scientific research and articles from the international and Greek domains, focusing on its potential to enhance individual technical skills and the movement of athletes, both with and without a ball. Scientific research was conducted using databases such as Web of Science, Google Scholar, ResearchGate and PubMed, with keywords including "basketball," "virtual reality," "individual technique," "basketball tactics," "offensive movements," and "defensive movements," along with their combinations. The literature review identified 26 relevant studies on the subject, excluding 11 due to their age and 10 for their lack of relevance. The remaining 13 studies, published in reputable journals, and 2 presented at international scientific conferences, examined the improvement of individual technique and athletes' movement with or without a ball. The analysis and categorization of these studies revealed that VR can be a significant complementary tool in the hands of coaches to enhance athletes' skills and movements on the court, with or without a ball.

Keywords: Basketball, virtual reality, individual technique, basketball tactics, offensive movements, defensive movements

Introduction

The rapid advancement of technology brings dramatic changes to training data, providing the opportunity for all involved to implement different/new techniques and changes in training methods (Zhao *et al.*, 2019) ^[1]. One of the most significant developments is the evolution of VR. VR is a technology that uses computers to simulate situations (such as F1 cockpit, etc.) and allows users to interact with their environment, whether virtual or real (Han, 2020; Zhigang & Weifan, 2019) ^[2, 3]. The equipment consists of glasses, gloves, and clothing that send data to the computer. Lessick and Kraft (2017) ^[4] define VR as the coexistence in two spaces, where one, the physical, is complemented by the other, the virtual, into which the user enters with the help of specialized technical equipment. Aukstakalnis and Blatner (1992) ^[5] state that VR is the means of interaction between computers and humans through which information is transferred, allowing users to see, hear, and act accordingly. VR allows users to move in a fictional environment, using their senses as if it were real, resulting in possible spatial and temporal simulation. In the literature, there is research connecting VR with sports (Balkó, Heidler, & Edl, 2018; Kim & Ko, 2019; Neumann *et al.*, 2018) ^[6, 7, 8].

Basketball is a popular sport where coaches aim, through training, for the continuous improvement of basketball players, learning, and improving individual technique and movement on the court (Heishman, Daub, Miller, Freitas, & Bembem, 2020) ^[9]. According to researchers, there are innovative and alternative ways to train and develop basketball players through VR technology, and significant results can be achieved (Li, 2022; Tsai & Hu, 2018; Zamzami, 2020) ^[10, 11, 12]. Therefore, the purpose of this research was, through the review of scientific studies and articles from the international and Greek domains, to investigate the existence of tools for evaluating VR in the field of basketball and to determine, if any, the positive and beneficial results in learning and improving individual

technical skills and movement of athletes with or without a ball. This work is particularly significant, as after studying the existing literature, basketball coaches will have alternative training methods to enhance the abilities of athletes and their team.

Methods

To offer a thorough summary of research involving virtual reality (VR) interventions designed to improve individual technical skills and athletic movements, both with and without a ball, scholars conducted a review and narrative synthesis of findings (Bates, 2022; Gunnell, Belcourt, Tomasone & Weeks, 2022) ^[13, 14]. This method, commonly employed in disciplines like anthropology, economics, psychology, and sociology, serves to present and amalgamate the current state of research, guiding future investigations in a specific field (Frank and Hatak, 2014; Fisch and Block, 2018) ^[15, 16]. The search and review process unfolded as follows:

The researchers utilized search platforms, including Web of Science, Google Scholar, ResearchGate and PubMed, with the last searches conducted on December 14th, 2023.

Various searches across all platforms employed English keywords and their combinations, such as "basketball," "basketball technique," "basketball tactics," and "virtual reality."

Additionally, reference lists of relevant articles were scrutinized to identify further studies. Gray literature, including theses, newspaper articles, and comments, was excluded (Gunnell *et al.*, 2022) ^[14]. Papers not aligning with the review's scope, like opinion pieces on using VR for athletes, were also excluded (Düking, Holmberg & Sperlich, 2018) ^[17].

The literature search and preselection yielded 26 articles, each of which underwent scrutiny for basic details (authors, year, journal, sport, sample, peer-review status, etc.). Specific characteristics and relevant factors, such as intervention programs, performance factors, aims, and

results, were extracted and coded from each article in detail. Data were collected and documented for all outcomes. The extraction of study characteristics and the determination of whether a study met inclusion criteria were initially conducted independently and then achieved through consensus among all authors. The review articles primarily focused on studies employing head-mounted displays but also encompassed VR settings with screens. Inclusion criteria led to the final inclusion of 15 out of the 26 preselected articles in this review, based on study type (intervention study with pre-post comparison) and study quality assessment (critical appraisal; Tod, Booth & Smith, 2022) [18]. Notably, inclusion criteria considered peer-review status (only peer-reviewed articles included) and journal

source (conference papers were also included). The deliberate emphasis on intervention studies with a pre vs. post design aimed to provide a comprehensive overview of VR interventions and their effects on real-life performance up to this point. The results are synthesized qualitatively, featuring a descriptive analysis and narrative synthesis in the following section.

Results

An essential question for researchers was whether the use of VR aids in learning and improving individual basketball techniques. Table 1 provides an overview of the 15 intervention studies and shows their main characteristics.

Table 1: Summary and primary attributes of the 15 intervention studies incorporated in the review

Year	Authors	Research title	Aim	Experimental group	Intervention Program	Results
2015	Morice, Goulon, Ibáñez-Gijón, Buekers, & Montagne	Prospective control of free-throw in basketball: Validation of a virtual setup and de-correlation methodology	Create Free throw simulator	Basketball players		It helps with free throw shots
2017	Tsai, Chung, Pan, & Hu	Train in virtual court: Basketball tactic training via virtual reality	Learning to move with or without a ball	60 (41 men and 19 women) in two groups. Control group (16 men and 14 women). Experimental (25 men and 5 women)	Three stages: a) Teaching tactics in a conventional way by all, b) tactics in a conventional way by the control group and with VR by the experimental, c) filling in a questionnaire	The use of VR improves the movement of athletes with or without the ball
2018	Li	Application of virtual environment in the teaching of basketball tactics	Collecting basketball athlete data with XsensMoven and converting it into animation characters			Creating animations for teaching needs
2018	Tsai, & Hu	Training assistant: strengthen your tactical nous with proficient virtual basketball players.	Drive input device with or without ball using VR			Learning to move with or without a ball
2019	Cannavò, Calandra, Basilicò, & Lamberti.	Automatic Recognition of Sport Events from Spatio-temporal Data: An Application for Virtual Reality-based Training in Basketball.	Collection and analysis of athletes' movements data with or without a ball			Planning player movements with or without a ball by a coach, and execution by athletes
2019	Pagé, Bernier, & Trempe	Using video simulations and virtual reality to improve decision-making skills in basketball	VR to instruct the right move with or without the ball	Three groups: a) control group (CTRL), b) VR group and c) Video (CS)	Four training sessions. CTRL team watched NCAA games. The CS monitored movements on a PC screen and the VR team dealt with VR drills.	The CS team training is transferred from the classroom to the court while The VR is transferred to the court with multiple applications
2020	Tsai, Pan, & Hu	Feasibility study on virtual reality based basketball tactic training.	Motion recording with cameras and analysis of the trajectory of movement of athletes with or without ball			The recommended VR and tablet system helps to understand the movement of athletes on the field
2020	Ma, Wang, & Liu	Feasibility analysis of VR technology in basketball training	Using matlab2014a software to track basketball players			VR as a tool of: a) presentation and motion planning, b) protection from injuries
2020	Zamzami	The effectiveness of using virtual reality technology on learning	VR use in jump shot learning	45 beginner basketball students. Three	The VR team, the group with verbal instructions for the jump-shot, and the control	Significant improvement of the jump-shot in the group with verbal

		the jump-shot skill in basketball		random groups (15 in each group)	group. 5 jump shots were tested and 20 shots were recorded	instructions and in the one with the use of VR. No changes to the control group
2021	Chen	Application of Computer Virtual Technology in Basketball Training	The use of Virtual Point Opti Tack in training athletes. Recording and analysis of the movements of top athletes			Recording and comparing the movement of athletes with that of top basketball players
2022	Jiang, Wu, & Zhang	Design and research of VR basketball teaching system based on embedded intelligent sensor.	Learning basic skills in basketball (shooting, dribbling etc.)	51 beginners of whom 26 experimental and 24 CTRL.	Six-month program duration. Measurements before and after the end of the program with motion sensor. VR use and on-field application by the experimental team. CTRL group only on the field.	VR team demonstrated better results in learning basic basketball skills
2022	Wei, Qin, Yan, & Wang	Application Effect of Motion Capture Technology in Basketball Resistance Training and Shooting Hit Rate in Immersive Virtual Reality Environment	Basketball players shooting enhancement with VR	30 athletes of different gender, age and height	Program duration: two weeks. Measuring accurate shots before and after the program	VR improved athletes' success rates with a higher of 14% and a lower of 4%.
2023	Soltani & Morice	A multi-scale analysis of basketball throw in virtual reality for tracking perceptual-motor expertise	Success rate of shots from different distances, ball trajectory and body movement	Twelve experienced (3 women and 9 men) and ten beginners (5 women and 5 men)	They executed 3 shots in a virtual basket from 3 different points. It was preceded by warm-up in a real basket (10+10 shots) and VR familiarization (10 shots)	The athletes estimated the distance and executed shots as if it were a real basket with the ideal trajectory and movement
2023	Liu, Liu, & Ni	Motion capture method for college basketball training based on AR/VR technology	Simulator control	10 persons	Control of 12 points of human body, in 9 movements, for accuracy and response time (dribbling, passing, shooting, defense, lay-ups, running, go, stationary, cover)	Shooting and defense percentages were approximately 85 %, while accuracy rates of other actions reached 93 % or higher. 92% consider it important to use VR. 86% that it is near real action and 66% said that it is easy to use
2023	Morice, Soltani, & Link	Getting past basketball defender is not just a matter of size	VR use affects one-on-one shooting decision	Twenty experienced and nineteen beginners were divided into two groups, tall and short	Athletes had to decide whether to shoot into virtual basket while obstructed by a virtual moving defender (6 different offensive-defensive distances)	Shooting decision is linked to the somatometric characteristics of the basketball player

Particularly, Morice, Goulon, Ibáñez-Gijón, Buekers, and Montagne (2015) ^[19] developed a simulator to enhance athletes' performance in free-throw shooting. Results indicated the simulator as a promising tool for beginners to learn free-throw shooting but emphasized the need for further research. However, no subsequent work from them was presented in the following years to confirm their findings. The authors highlighted the importance of using VR not only in free-throw technique but overall, in learning and improving athletes' individual basketball techniques.

Li (2018) ^[20] attempted, using VR technology, to capture three-dimensional data and simulate traditional teaching methods. They employed a virtual model of basketball players to design individual player techniques. The physical movements of players were transformed into three-dimensional motion using the XsensMoven system, tracking and recording athletes' movements in real-time. The results

showed that VR helped achieve goals faster, making training more effective.

Similar purposes were pursued by Ma, Wang, and Liu (2020) ^[21], who used VR to assess movement learning and the enjoyment it offers to athletes. The motion information collection tool included six high-speed cameras, a synchronization camera, and other data collection equipment. They created a sports motion model, analyzing and comparing it with athletes' movements. The kinetic model simulating athletic motion proved to be particularly significant, enhancing the role of VR not only as a presentation medium but primarily as a design tool. By creating a three-dimensional virtual space, it achieved a dual purpose of learning and entertainment.

Beyond improving individual techniques, the movement of athletes with or without the ball plays a significant role in basketball. Researchers, such as Tsai, Chung, Pan, and Hu (2017) ^[22], utilized simulators for learning and improving

movement with or without the ball. Through VR, athletes could experience how a movement was executed from both the spectator's and player's perspectives, enhancing their understanding and allowing for practice. VR made athletes feel like they were playing in a real game while learning new moves simultaneously.

In their work, Tsai & Hu (2018) ^[11] advocate the crucial role of offensive movements in basketball. Utilizing Virtual Reality (VR), they create offensive movement learning schemes. They emphasize the significance of both the space in which the athlete moves and the timing of passes, dribbles, and movements towards the basket, all in relation to defensive actions. The VR device consists of an input device and a wireless interaction system, allowing users to easily input offensive movements. Through the VR training system, players can comprehend the execution of movements by observing them from the perspective of different athletes. The inclusion of virtual defenders with artificial intelligence makes the training realistic. Using the proposed learning scheme, players engage in and practice offensive movements of team athletes off the court, enhancing their knowledge and effectiveness.

Another study by Cannavò, Calandra, Basilicò, and Lamberti (2019) ^[23] also explores the use of VR in learning basketball movements. They employed an existing VR tool, Playbook, providing coaches with graphics to design player movements with or without the ball in a two-dimensional space (tablet). The tool then generates the corresponding three-dimensional moving plan, visualized simultaneously by multiple players wearing VR glasses. This tool allows coaches to manage and simulate movements from previous games, creating different moving plans with virtual teammates and opponents, thereby increasing the realism of the simulation.

Chen (2021) ^[24] argues that the Virtual Point Opti Tack infrared motion capture technology extracts data, enhancing training efficiency. Coaches analyze data from top world athletes, compare it with their athletes' data, and guide them to improve movement execution. With the introduction of VR training systems, athletes can use VR equipment to enhance their skills and simulate training anytime, anywhere. Additionally, this motion capture technology, combined with a force measurement system, provides valuable information on the stresses athletes undergo, such as in the shin and knee areas, helping protect athletes from skeletal injuries.

Tsai, Pan, & Hu (2020) ^[25] design a multi-camera monitoring system around the basketball court to collect athlete motion data (speed, trajectories, etc.). The system includes a VR device and a tablet. Their goal is to assess the importance of VR in learning movements with or without the ball. The results show that the proposed system is a useful tool for learning complex tactical movements of players with or without the ball.

Beyond research confirming the use of VR in learning technical and movement skills in basketball, there are studies that reinforce its significance. Pagé, Bernier, and Trempe (2019) ^[26] examined the effectiveness of video and VR in decision-making improvement. They investigated whether this improvement is transferable from the laboratory to the field and applicable from known to unknown game situations. To explore these questions, basketball players participated in four training sessions during which they watched basketball game videos on a computer screen (CS group) or used VR headsets. Decision-

making was evaluated on the field before and after training sessions using two types of games: pre-known games and games without prior training. When facing pre-known games, both the VR group and the CS group outperformed the control group. Conversely, in games without prior training, the VR group showed better performance than the other two groups. The results indicate that VR training can transfer from the classroom to the field, unlike CS training, making it a versatile tool.

Zamzami (2020) ^[12] investigates the effectiveness of Virtual Reality (VR) technology in teaching the jump-shot in basketball. The study involved 45 novice basketball students focusing on jump-shot execution. Three random groups were created: the VR group, another with verbal instructions for the jump-shot, and a control group. Measurements were taken before and after program implementation. The VR group used the HTC Vivek VR headset for jump-shot instruction. Results showed significant improvement in jump-shot execution in both the verbal instruction group and the VR group, while no change was observed in the control group. There were no significant differences between the two experimental groups, confirming the importance of VR use.

Coaches of recognized value instructed two groups of students, an experimental group, and a control group, selected to participate in Jiang, Wu, & Zhang's (2022) ^[27] research. The experimental group received basketball shooting skill instructions using VR, while the control group was informed through traditional methods. The program lasted for six months, and the majority of students in both groups were beginners. The shared court space aimed for more effective program supervision by both groups. Measurements were taken at the beginning and end of the research, demonstrating the superiority of the VR-using group over the control group, as revealed by motion control recordings of basic skills.

Soltani and Morice (2023) ^[28] emphasize the importance of VR in training as a supplementary tool for improving athletic performance. They investigated success rates of shots at different distances, ball trajectory, and body movement, finding that players perceived the virtual environment realistically. The study involved experienced and novice players executing virtual shots, indicating that players understood the distance to the virtual basket and performed as if it were real. Coaches can rely on VR simulation as a complementary aid for assessing player differences and comparing cognitive abilities.

Wei, Qin, Yan, and Wang (2022) aimed to improve basketball players' shooting technique using VR motion capture technology. They recorded and analyzed shooting movements to enhance shooting success rates. Results from 30 athletes of different genders, ages, and heights showed significant improvement in shooting success rates, especially for athletes of different heights. While the study had a short duration, it provided reliable results, suggesting the future need for longer-term application of the new technology.

Liu, Liu, & Ni (2023) propose motion capture using VR technology to enhance skill efficiency. They describe the steps of the VR motion capture method, recording and creating three-dimensional motion, speed, joint angle, and angular velocity data. Experimental measurements evaluated athletes' performance accuracy and response time, with high accuracy rates for shooting and defense actions. The majority of respondents considered VR equipment important

for training, approaching real action, and causing no difficulties in use.

Morice, Soltani, and Link (2023) [28] argue that decision-making in one-on-one situations is influenced by VR, providing a representation of the opponent's movements. Their study examined athletes' perceptions and placed a virtual defender at various distances during a simulated shooting task. Results indicated that the decision to shoot was influenced by the increasing distance from the virtual defender. Body height, experience, and the ability to jump also played a role, with athletes shooting more when allowed to jump. The study suggests that decision-making is linked to somatometric characteristics, emphasizing the importance of player awareness in one-on-one situations.

From the analysis and categorization of the research, the following findings have emerged:

- a. The use of Virtual Reality (VR) is beneficial as a means to enhance individual technique.
- b. The utilization of VR is effective in improving the movement of athletes, whether they are holding a ball or not.
- c. The incorporation of VR as an alternative exercise method provides participants with entertainment.
- d. VR serves as an additional tool for the improvement of basketball players.

These results underscore the positive impact of VR technology in various aspects of basketball training, emphasizing its potential not only for technical skill enhancement but also as an enjoyable alternative exercise method for athletes. The findings position VR as a valuable supplementary tool in the continuous development of basketball players' abilities.

Discussion

Modern technology, particularly Virtual Reality (VR), is fundamentally transforming the landscape of contemporary basketball training. It provides flexibility by transcending the constraints of space and time. In other words, today's basketball athlete can navigate the VR environment, engaging all their senses, with remarkable results in the actual playing field, i.e., the court. This is even more pronounced now, given the availability of reliable tools for learning and improving techniques and movements, both with and without the ball. These results manifest directly in the competitive arena.

For example, VR technology that records players' movements offer greater precision in analysis, leading to crucial interventions and, consequently, training improvement. The capturing of high-level athletes' movements (jump shots, free throws, etc.) and their movements with or without the ball using VR technology yield a wealth of information and data. These data are analyzed and transformed into supportive tools for coaches in designing more effective training plans.

Moreover, VR technology makes training enjoyable, countering the fatigue and reluctance often associated with exercise repetitions. Athletes can use VR to observe, practice, and enhance their movements in "real-life conditions," with or without opponents.

This new reality proves particularly useful as coaches can tailor exercises to the individual needs of each athlete, resulting in rapid individual improvement and, by extension, team enhancement. VR can transfer knowledge from the virtual to the real environment, making it applicable in

unfamiliar situations. Athletes also have the option, through a wide range of choices, to make the appropriate movements to achieve their goals. Additionally, the risks inherent in daily training are minimized with this new technology, safeguarding athletes from serious injuries that can often impact their professional futures. Finally, VR technology aids in the return of injured athletes to competitive arenas who are undergoing preparation and cannot follow their team's physical training.

In conclusion, new technologies lay the groundwork for a different approach to basketball, based on a more scientific utilization of data and advancements in the field. Coaches now have a new tool that can significantly improve not only the skills of active athletes but also attract the interest of new individuals, as these technologies are particularly appealing to them. However, it should be noted that this is not a replacement for traditional training methods but a supplement for optimal results. For this reason, further research should expand and delve deeper for tangible results in the near future.

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