# Beyond the Court: How Virtual Reality is Changing the Game for Athletes

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| ARTICLE INFO | ABSTRACT |
|---|---|
| | Virtual reality technology creates a simulated environment that can make users feel as if they are fully immersed in a different world or experience. This is accomplished through the use of specialized headsets and controllers that track the user's movements and translate them into actions within the virtual environment. The aim of this bibliometric review is to locate scholarly literature that explores the use of virtual reality in sports and training. To gather data, Scopus citation databases were utilized, and the PICOS Framework and PRISMA approach were employed to conduct a keyword search. Data on articles published in journals over a seven-year period was extracted, and R-tool and VOS viewer were utilized to analyse the data contained in the journals and articles. Through this bibliometric review, the utilization of virtual reality technology in sports and training is revealed. A total of 56 articles were identified from the Scopus database, and the findings showed that the keyword "artificial intelligence" had an occurrence value of 27 with a Total Link Strength (TLC) of 15. This was followed by "machine learning" with an occurrence value of 12 and a TLC value of 8. The United States of America and the United Kingdom were found to be the leading countries in publishing and conducting research related to VR in sports and training. Furthermore, the application of VR in sports showed a high significant value, but there are some limitations and challenges in its expansion. Therefore, through this study, it is important to identify the exposure related to the use of VR to be conveyed to coaches and trainers. However, the past studies analysed in this review indicate the need for exposure in the form of education on the use of VR to ensure the full utilization of current technology in sports. |
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## 1. Introduction

Virtual reality has become an increasingly prevalent technology in various fields, including sports. With its ability to create immersive and realistic environments, virtual reality has the potential to revolutionize the way athletes train, compete, and recover from injuries. By simulating game situations and providing interactive experiences, virtual reality can enhance athlete performance,

reduce the risk of injuries, and provide an innovative and engaging experience for fans [1]. In this review article, we will explore the various ways in which virtual reality is changing the game for athletes, including in sports training, injury prevention and rehabilitation, broadcasting, and athlete performance analysis. Additionally, we will examine the challenges and future directions of virtual reality in sports, and the potential impact it may have on the future of athlete performance.

Virtual reality can enhance sports training by providing immersive and realistic environments for athletes to practice and refine their skills. Virtual reality training can improve basketball shooting performance and cognitive processing speed [1]. Virtual reality can reduce the risk of injuries in athletes by providing a safe and controlled environment for training and rehabilitation. A recent study found that virtual reality balance training can improve balance and reduce the risk of falls in older adults [2].

Virtual reality can provide an innovative and engaging experience for sports fans by allowing them to interact with the game in new ways. Virtual reality sports broadcasting can enhance fan engagement and satisfaction [3]. Virtual reality can enhance athlete performance analysis by providing more accurate and detailed data on athlete movements and behaviors. Despite the potential benefits of virtual reality in sports, there are still challenges to be addressed, such as cost, accessibility, and technical issues. A recent review discusses the current challenges and future directions of virtual reality in sports, and suggests strategies for overcoming these challenges [4].

Virtual reality (VR) has the potential to revolutionize sports training by providing immersive and realistic environments for athletes to practice and refine their skills. With VR technology, athletes can simulate game situations and receive immediate feedback on their performance, allowing them to improve their skills in a safe and controlled environment.

Recent research has explored the effectiveness of VR in sports training. The effect of VR-based training on basketball shooting performance and cognitive processing speed [1]. The athletes who received VR training showed significant improvement in basketball shooting performance and cognitive processing speed compared to those who received traditional training methods [1].

VR training on golf swing mechanics and the study found that VR training was effective in improving golf swing mechanics and reducing swing variability [5,6]. Moreover, the study found that the improvements gained from VR training were transferable to real-world performance.

In addition, VR technology can also be used in sports injury prevention and rehabilitation. The VR-based balance training in reducing the risk of ankle sprains in soccer players [7]. The study found that VR-based balance training was effective in reducing the risk of ankle sprains in soccer players. One of the key advantages of VR-based sports training is the ability to create highly realistic and customizable scenarios. For example, basketball players can practice shooting under different defensive pressures or golfers can simulate playing on different courses. This level of realism can help athletes to prepare for real-world game situations, making them more confident and better prepared when they step onto the court or field.

Moreover, VR-based training has been found to be highly effective in improving sports performance. The impact of VR-based training on baseball players' batting performance [8]. The study found that athletes who received VR-based training showed significant improvements in batting performance compared to those who received traditional training methods.

However, there are also some limitations to VR-based sports training that need to be addressed. One of the main concerns is the cost of VR technology, which can be prohibitively expensive for many athletes and sports teams [9]. Another concern is the lack of standardized training protocols and guidelines, which can make it difficult to assess the effectiveness of VR-based training across different sports and disciplines [10].

In conclusion, VR technology has the potential to transform the way athletes train and prepare for sports competitions. With further research and development, VR-based training could become an essential tool for athletes looking to improve their skills and performance [11]. However, it is important to address the challenges and limitations associated with VR-based training to ensure that it is accessible and effective for all athletes.

Virtual reality (VR) technology has been extensively researched in sports training, and while it holds immense promise, there are still several challenges to be addressed [12]. One of the main concerns is the lack of standardization in VR research methodologies. As noted by Laver *et al.,* [13], there is a lack of standardized protocols for VR research in sports training, making it difficult to compare results across studies. This lack of standardization can lead to inconsistencies in the findings and limits the ability to draw definitive conclusions about the effectiveness of VR-based training. Besides, VR in sports training is the lack of physical feedback. While VR can provide visual and auditory feedback, it cannot provide the same level of physical feedback that athletes experience in real-world situations. For example, VR cannot replicate the weight, texture, and resistance of equipment or the impact of a collision or tackle.

Another challenge is the need for more research on the transferability of skills learned in VR-based training to real-world game scenarios. There is a need for more research on the transferability of skills learned in VR-based training to real-world game scenarios [14]. Without this research, it is difficult to determine the true effectiveness of VR-based training in improving performance in real-world game scenarios.

Additionally, there is a need for more research on the long-term effects of VR-based training. According to a study by Zhang *et al.,* [15], there is a lack of research on the long-term effects of VR-based training on athlete performance. More research is needed to determine whether the improvements in performance observed in short-term studies can be sustained over the long term. To fully realize the potential of VR in sports training, these challenges need to be addressed through further research and standardization of protocols. By doing so, VR-based training can become an effective and accessible tool for improving the performance of athletes in a range of sports and disciplines. This study aims to explore use of virtual reality technology in sports and training. VR-based training offers a unique and immersive learning experience that has several noteworthy implications. Here are research questions for a bibliometric analysis on Virtual Reality is changing the game for Athletes:

(i) What are the most common keywords and topics related to Virtual Reality is changing is the game for athletes, and how have they changed over time?

(ii) Which countries or regions are most active in publishing research on Virtual Reality is changing is the game for athletes?

(iii) How far has the Virtual Reality applications used in sports training research progressed in the publication?

(iv) What are the most common types of Virtual Reality applications used in sports training, and how effective are they?

(v) How has the research on Virtual Reality in Sports Training evolved over time, and what are the emerging trends and areas for future research?

## 2. Methodology

To address all research questions, this study utilized the PRISMA method as shown in Figure 1 (Preferred Reporting Items for Systematic Review and Meta-Analysis) and Bibliometric analysis. The PRISMA method was employed to filter and choose articles from Scopus databases that pertained to

the research topic. Additionally, the approach can be replicated by other researchers to discuss the same topic. Table 1 presents the criteria used to include and exclude articles when shortlisting them from the Scopus database.

**Table 1**
Inclusion and exclusion criteria

| Inclusion criteria | Exclusion criteria |
| --- | --- |
| Documents published in 2017-2023 | Documents published before year 2017 |
| Documents published in English or Malay Language | Documents that are duplicates or substantially similar to |
| Documents focusses on Virtual Reality in sports | Documents that are not peer-reviewed or are not considered to be scholarly |

**Topic, Scope & Eligibility**

- **Topic** → Virtual Reality in Sports Training

- **Scope & Coverage** →
  **Database:** Scopus
  **Search Field:** Article Title
  **Time Frame:** 2017-2023
  **Language:** English
  **Source Type:** Journal
  **Document Type:** Article

- **Keywords & Search String** →
  TITLE-ABS-KEY (Virtual Reality in Sports Training AND Virtual Reality in Sports " OR "VR in sports" OR "VR in sports training) AND LIMIT-TO ( PUBYEAR , 2017 TO 2023)) AND ( LIMIT-TO ( LANGUAGE, "English" ) ) AND ( LIMIT-TO ( SRCTYPE,"j" ) )

- **Date Extracted** → 06 March 2023

**Screening**

- **Record Identified & Screened** → n = 68

- **Record Removed** → Refine 1: Document type: exclude erratum (n=4)

**Included**

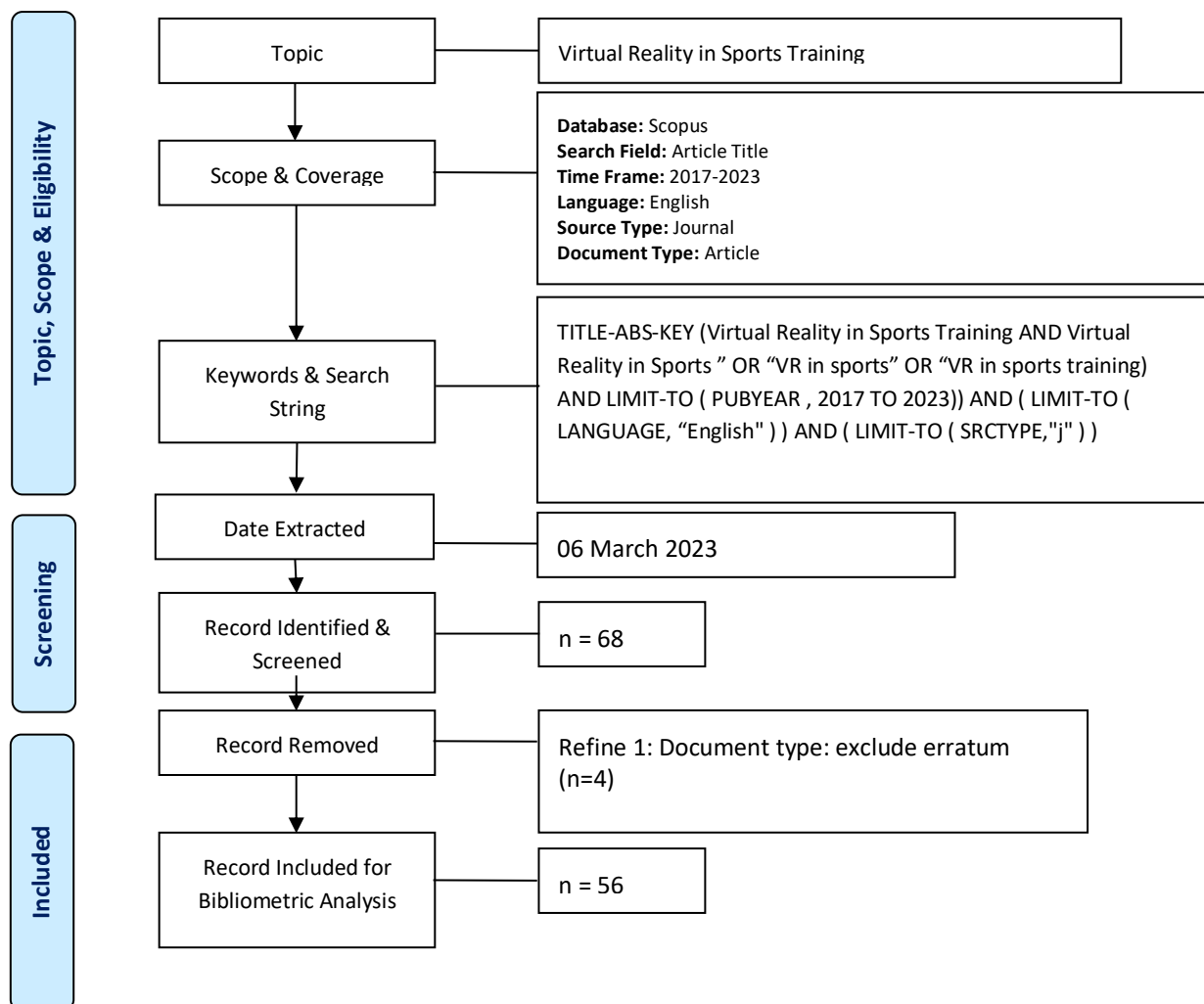- **Record Included for Bibliometric Analysis** → n = 56

**Fig. 1.** PRISMA flowchart of data inclusion and exclusion [16]

All English articles from year 2017 to 2023 were examined in this study. Four erratum reports were excluded to avoid duplication, resulting in 56 unique records that were downloaded for further analysis. Table 2 shows the four sets of keywords that were used to select and narrow down the articles from the Scopus database. The primary keyword was Virtual Reality in Sports Training, while the secondary keyword was Virtual Reality in Sports. Table 2 also displays the keywords used in this

bibliometric analysis, including virtual reality and model, which were combined with either "AND" or "OR" operators.

**Table 2**
List of keywords

| Keyword set | Keywords |
|---|---|
| Keywords_set 1 | Virtual Reality in Sports Training |
| Keywords_set 2 | Virtual Reality in Sports |
| Keywords_set 3 | VR in sports |
| Keywords_set 4 | VR in sports training |

## 3. Finding

In this study, a combination of performance analysis and bibliometric analysis was used to address the research question. Bibliometric analysis involves collecting and analyzing bibliographic data, such as publication dates, authors, journals, and citation counts. The data is then used to generate statistics and metrics, such as the number of publications, the number of citations, the h-index, and the g-index. These metrics can be used to identify trends, patterns, and gaps in the literature and to evaluate the impact of individual authors, institutions, and countries.

Bibliometric analysis provides a valuable tool for researchers, policymakers, and funders to assess the state of research in a particular field and to make informed decisions about future directions and investments. To conduct citation and publication analysis, the Bibliometrix R package and Perish software were utilized, based on Harzing's [17] approach. Author's keywords were mapped using VOSviewer software, which identified the study's significance and involved VR clusters. The study's centrality was determined using Total Link Strength (TLS), while the density of the scope was used to measure the internal strength or level of interaction within a network. Additionally, novelty was determined by comparing the average publication year to the median value, where studies with an average publication year greater than or equal to the median were considered novel.

*3.1 Most Common Keywords and Topics Related to Virtual Reality in Sports*

The bibliometric analysis in Figure 2 shows the use of keywords in the 56 studies selected for this analysis. Keyword analysis is a key component of bibliometric analysis that involves examining the frequency and distribution of specific words or phrases in scholarly publications to identify trends and topics of interest. Keyword analysis provides a valuable tool for analysing the patterns and trends of research in a particular field, identifying influential articles, authors, and journals, and evaluating the impact of research. The findings in Table 3 show that ten sets of keywords were chosen by the article authors. Among them, artificial intelligence had an occurrences value of 27 with a Total Link Strength (TLC) of 15. This was followed by machine learning with an occurrences value of 12 and a TLC value of 8.
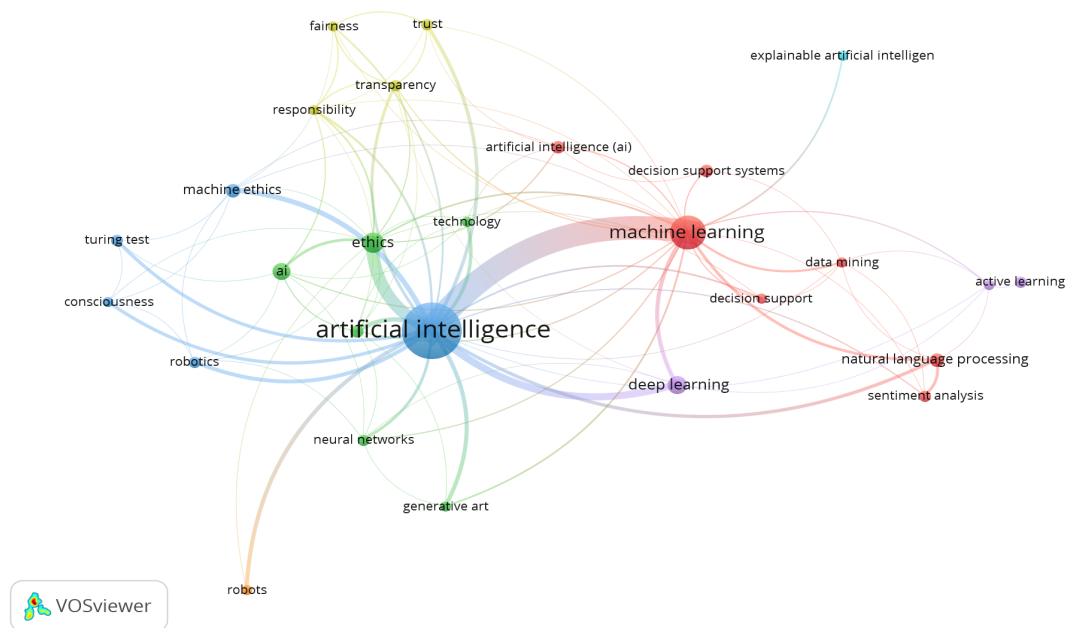
**Fig. 2.** Keyword analysis on VR in Sports and Training from year 2017-2023

**Table 3**
Keyword analysis

| Keywords | Occurrences | Total Link Strength |
|---|---|---|
| Artificial Intelligent | 27 | 15 |
| Machine Learning | 12 | 8 |
| Natural Language Processing | 15 | 12 |
| Robotic | 10 | 12 |
| Technology | 8 | 12 |
| Sentiment Analysis | 11 | 11 |
| Machine Intelligence | 5 | 8 |

*3.2 Countries or Regions Most Active in Publishing Research on Virtual Reality in Sports*

The study findings indicate that a total of 56 articles were identified in the Scopus database, which conducted research on the integration of VR technology in sports and exercise. The findings show that eight studies were conducted in the United States of America, followed by three studies in the United Kingdom. Meanwhile, Germany, Italy, and the Netherlands conducted two studies each. However, no studies were found in Malaysia in the Scopus database for the period from 2017 to 2023. Figure 3 shows the countries that have published the most research related to the use of VR in sports and exercise in Scopus.
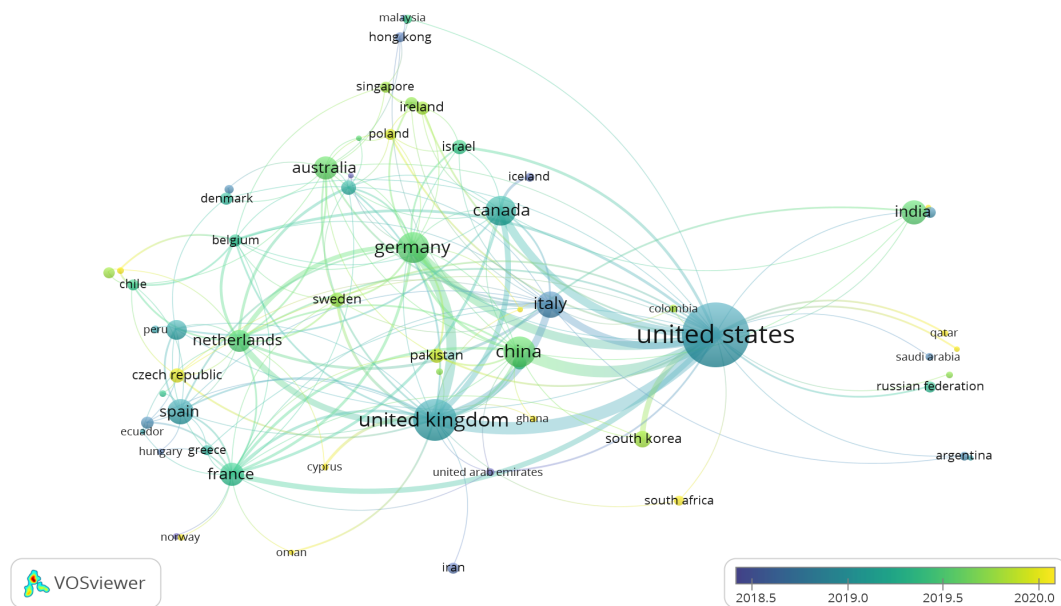
**Fig. 3.** Total Publication and citation on VR in Sports and Training from year 2017-2023

*3.3 Virtual Reality in Sports Research Progressed in the Publication*

For this study, 56 publications on VR in sports research were obtained from the Scopus database. The first publication from 2017, "Boccia: Kinematics of the throwing and its relationship with virtual realityBocha," was included in the analysis. The number of publications related to VR in sports remained in the single digits from 2017 to 2018, but has steadily increased since then (as shown in Table 4 and Figure 4). The trend line indicates that the number of publications is increasing polynomial (with an $R^2$ of 784), which is a more significant increase than a linear one.

**Table 4**
Annual total citation

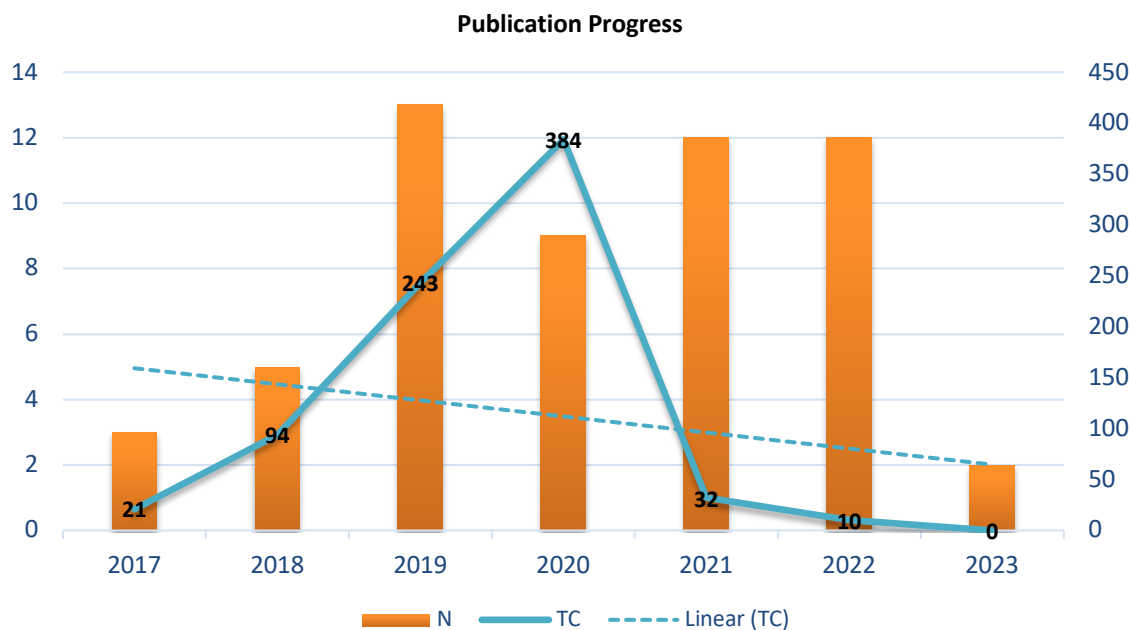| Year | N | TC | Mean TC per Art | Mean TC per Year | Citable Years |
|------|----|-----|------------------|-------------------|----------------|
| 2017 | 3 | 21 | 7 | 1.00 | 7 |
| 2018 | 5 | 94 | 18.8 | 3.13 | 6 |
| 2019 | 13 | 243 | 18.69 | 3.74 | 5 |
| 2020 | 9 | 384 | 42.67 | 10.67 | 4 |
| 2021 | 12 | 32 | 2.67 | 0.89 | 3 |
| 2022 | 12 | 10 | 0.83 | 0.42 | 2 |
| 2023 | 2 | 0 | 0 | 0.00 | 1 |
| Total | 56 | 784 | | | |

**Fig. 4.** Total Publication and citation on VR in sports and training from year 2017-2023

### 3.4 Most Common Types of Virtual Reality Applications Used in Sports Training

Virtual Reality (VR) technology has become increasingly popular in sports training due to its ability to provide athletes with a realistic and immersive training environment. Some of the most common types of VR applications used in sports training include:

(i) Immersive 360-Degree Video: This type of VR technology provides athletes with a 360-degree view of a real-world training environment. The athlete wears a VR headset and can look around in all directions to see the environment. This technology has been used in sports such as basketball, where athletes can experience what it's like to be in the middle of a game and make decisions in real-time [18].

(ii) Motion-Capture Technology: This type of VR technology tracks an athlete's movements and provides real-time feedback on their technique. This technology has been used in sports such as golf, where athletes can see their swing in 3D and make adjustments to improve their performance [19].

(iii) Virtual Reality Simulations: This type of VR technology creates a simulated training environment that allows athletes to practice specific skills or scenarios. This technology has been used in sports such as football, where quarterbacks can practice reading defenses and making throws in a simulated game environment [20].

Based on the finding, VR technology has the potential to reform sports training by providing athletes with a realistic and immersive training environment that can improve their skills and performance.

### 3.5 Research on Virtual Reality in Sports Training Evolved over Time, and the Emerging Trends

Research on Virtual Reality (VR) in sports training has evolved over time as technology has advanced and the benefits of VR have become more widely recognized. Early research in this area

focused on demonstrating the potential of VR technology to improve athlete performance by providing realistic and immersive training environments. More recent research has focused on understanding the underlying mechanisms that drive the effectiveness of VR training and identifying ways to optimize its use.

One emerging trend in research on VR in sports training is the use of physiological and neuroimaging techniques to investigate the impact of VR training on brain function and motor learning. For example, Seiler *et al.,* [21] mentioned used functional magnetic resonance imaging (fMRI) to examine the neural mechanisms underlying the effects of VR training on golf putting performance. The study found that VR training resulted in changes in brain activity that were associated with improved performance.

Another emerging trend is the use of machine learning and artificial intelligence (AI) techniques to personalize VR training programs for individual athletes. Machine learning algorithms to analyse data from motion capture sensors and customize VR training programs for basketball players based on their individual strengths and weaknesses [22].

Finally, there is growing interest in the use of VR technology to enhance athlete mental skills, such as attention and visualization. A study by Panchuk *et al.,* [23] found that VR training improved the visual search performance of elite soccer players, suggesting that it may be a useful tool for enhancing cognitive skills that are critical for success in sports.

Research on VR in sports training has evolved from demonstrating its potential to improve performance to understanding the underlying mechanisms and optimizing its use through personalization and integration with other training methods. The emerging trends in this field suggest that VR technology will continue to play a significant role in sports training in the years to come.

## 4. Challenges and Future Directions

Virtual Reality (VR) has emerged as a promising technology that has the potential to transform the sports industry by offering an immersive experience to both fans and athletes. Despite its infancy, the use of VR in sports has encountered significant hurdles that must be addressed to unlock its full potential. According to a report by PwC, the high cost of VR equipment is a significant barrier to widespread adoption in sports. The report states that the cost of VR equipment must come down significantly before it can become a mainstream technology in the sports industry [24].

A study published in the Journal of Sports Sciences found that some users experience motion sickness when using VR equipment, which can be a significant barrier to its adoption in sports [25,26]. The study suggests that improving the response time of the VR environment to users' movements could reduce the incidence of motion sickness [25]. Creating a truly realistic VR sports experience requires high-quality graphics and accurate physics modeling. A report by Juniper Research suggests that advances in graphics technology and the development of new haptic feedback systems will be crucial for improving the realism of VR sports experiences [27,28].

Integrating VR technology into existing sports venues or broadcasts can be a significant challenge. A report by Deloitte suggests that sports organizations will need to invest in new infrastructure and equipment to integrate VR into their operations fully [27].

Future directions for VR in sports could include the development of more immersive and interactive experiences, such as using haptic feedback to simulate physical sensations like impact and temperature changes. Additionally, the use of VR technology in sports training and rehabilitation could be expanded, providing athletes with a safe and controlled environment to practice and recover from injuries [29,30]. In addition to the benefits mentioned above, future directions for VR in sports training could include the development of more advanced simulation systems that can

replicate real-life situations more accurately. VR systems that can simulate complex team sports like football or basketball would be of great value to athletes, coaches, and trainers [31].

Furthermore, VR technology could be used to personalize sports training programs for individual athletes. By analyzing data from sensors and other devices, VR systems can create personalized training programs based on an athlete's specific needs and goals [26,32,33]. This approach could help athletes achieve better results in less time and with fewer injuries [34-36]. As conclusion, the potential applications of VR in sports training and rehabilitation are vast and exciting. With continued research and development, we can expect to see significant advancements in this field in the coming years.

*4.1 Significance of Study*

The study of VR in sports and training has several significant implications for coaches, trainers, and other stakeholders in the sports business. First, VR can provide coaches and trainers with a tool to simulate game situations and scenarios, allowing athletes to practice their skills in a safe, controlled environment. This can help coaches and trainers identify weaknesses and areas for improvement in athletes' performance, and tailor training programs to address these areas. VR can enhance the learning experience by providing athletes with immediate feedback and the ability to review their performance from different angles. This can help athletes understand their mistakes and make corrections quickly, leading to faster skill acquisition and improvement. While, VR can help reduce the risk of injury by providing athletes with a safe environment to practice high-risk manoeuvres and techniques. This can help prevent injuries that may occur during real-world training, leading to better athlete health and performance. Finally, VR can provide new revenue streams for sports businesses. For example, VR training programs can be marketed and sold to teams and individual athletes, generating additional income for sports businesses. Additionally, VR can be used in fan experiences, such as virtual tours of sports facilities or immersive experiences during live games, creating new revenue opportunities for sports businesses.

## 5. Conclusion

In conclusion, Virtual Reality (VR) technology holds great promise for revolutionizing the sports industry. It has the potential to create immersive experiences for both fans and athletes alike. While the use of VR in sports is still in its early stages, it has already demonstrated significant benefits in areas such as sports training and rehabilitation. However, challenges such as cost, motion sickness, and integration remain, and they need to be addressed to unlock the full potential of VR in sports.

Looking forward, the future of VR in sports appears bright. Advances in graphics technology, haptic feedback, and data analytics will help to create more realistic, personalized, and interactive experiences. With further research and development, athletes can expect to see VR technology becoming an integral part of the sports industry, transforming the way athletes train and compete and offering fans new and exciting ways to engage with their favorite sports. In addition, VR technology offers the potential to integrate with other technologies, such as wearables, sensors, and data analytics, to create customized training programs for athletes [37,38]. This approach can lead to more precise and effective training tailored to an athlete's specific needs. Moreover, VR technology can be applied commercially in areas like sports broadcasting and advertising, creating new opportunities for revenue streams in the sports industry.

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