Physical Education Theory and Methodology
Теорія та методика фізичного виховання

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Review Article

The Role of Virtual Reality in Optimizing Karate Performance: Scoping Review

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: February 18, 2025
Published: March 30, 2025

DOI: 10.17309/tmfv.2025.2.25

Abstract

Objectives. The objective of this study was to undertake a scoping review on the role of virtual reality (VR) in optimizing karate performance. The questions to be researched were: (1) how did VR support the training process, (2) what were the challenges of integrating VR, (3) how effective was VR in maximizing performance, and (4) what was the potential of VR in the development of karate training methods.

Materials and methods. The scoping review was employed as a research method. The stages of research included (1) determining the title, (2) determining the study question, and (3) searching for the Scholar, Wiley, Scopus, and Springer database articles with the keywords used comprising Boolean "karate" and "virtual reality" or "VR". This article search yielded data from Google Scholar 77, Wiley 27, Scopus 52, and Springer 47. (4) The initial screening yielded 150 articles. (5) The second screening yielded 25 articles, and (6) the final data was determined, yielding 9 articles in all. The data collection and analysis techniques included Publish or Perish, Mendeley, and narrative interpretation.

Results. (1) VR is one of the successful applications to enhance karate training, providing a safe and adaptable approach. However, improvements to VR require further research to increase realism, content variation, clear instructions, and long-term testing to be more effective. (3) Combining conventional training and VR has emerged as the most effective method for enhancing karate performance. (4) While VR has positive potential, it is essential to refine the guidelines and standards of use before it can be extensively adopted.

Conclusions. The findings indicate that VR becomes a complementing and efficient training application for improving karate performance.

Keywords: virtual reality, performance optimization, sports technology, karate, scoping review.

Introduction

Virtual reality (VR) is no longer limited to education (Mannir & Getso, 2023). However, it is becoming more widely known and has evolved in the world of sports, particularly karate. VR is a breakthrough that will provide a new experience for training applications for beginners, intermediate, and professional athletes. Karate needs fast, strong, and precise motions, therefore the presence of VR aids in smooth training. Optimal karate performance demands a combination of striking and kicking techniques, strategy, tactics, and adequate physical condition (Hadi & Yudhistira, 2023; Yudhistira, 2023).

Karate is a physical contact sport (Yudhistira, Siswantoyo, et al., 2021; Yudhistira, Suherman, et al., 2021). There is a greater chance of injury in traditional training while approaching a match. The author's idealism demonstrates

that VR is a solution for bridging this visualization with real-world situations to enhance fighting skills while retaining the core of the sport of karate. According to another study, one of the barriers to achieving athlete potential in traditional karate training is a lack of sparring partners with various styles and variations, the risk of injury, and the need for structured training conditions (K Petri, Emmermacher, Masik, et al., 2019). These are the fundamental components for the creation of VR for the sport of karate among academics, particularly those from outside. At this point, virtual reality, particularly in the sport of karate in Indonesia, has not received special attention to be revealed in depth; this is the cause why the author performed this review to investigate the challenges and gaps in past research to discover meaning as a foundation for future study.

VR has evolved as an innovative approach to these difficulties by providing each athlete with a consistent, safe, and adaptable real-world environment (Witte et al., 2022). VR is a computer-based simulation technology that creates immersive three-dimensional settings in which sportsmen can interact with circumstances similar to real-world contests. VR is a tool for improving cognitive and motor skills, providing simulation strategies, visual feedback, and endless repetition in a safe environment (Ritter et al., 2022). Previous research has revealed that VR can increase response speed, movement accuracy, and attack recognition of patterns in karate, making it a suitable training tool for improving performance in real competitions (Ghazi et al., 2025).

However, despite its enormous potential, the use of VR in karate instruction confronts certain urgent problems that require immediate attention. First, there is inconsistency in transferring VR training to real-world performance, particularly in terms of physical engagement, adaptation to dynamic match conditions, and decision-making (Stefan Pastel et al., 2021; K Petri et al., 2018; Ritter et al., 2022). Second, there are still no standard criteria for implementing this technology, resulting in variability in training effectiveness and severely limiting innovation for coaches and players. Third, although VR gives extensive options, excessive training without genuine help from coaches might result in technical faults or dependence on the virtual world, potentially damaging to athletes in the long term (Witte et al., 2022).

Furthermore, financing for VR software and gear remains quite pricey, making it difficult for many clubs and athletes to gain access to this technology. In this situation, it poses challenges to the global implementation of VR technology, particularly in developing countries. As a result, it is critical to perform a scoping review study to assess the extent to which VR has been developed and implemented in the context of karate training.

A scoping review is a tool for mapping and exploring prior research by finding gaps, trends, and opportunities in the literature (Munn et al., 2018). Then use the total knowledge to generate future research. Given the availability of VR research in other sports, this approach is critical for integrating these findings into the context of karate, which has unique requirements such as reaction speed, movement pattern recognition, technique mastery, and field mastery that can be fulfilled in the actual world. Given the importance of ongoing VR development, this scoping assessment provides an excellent basis for future research.

Thus, the objective of this research is to conduct a scoping review of the role of VR in improving karate performance. The analysis of the most recent outcomes utilizing precise procedures and phases is expected to provide in-depth insight into the prospects, effectiveness, and challenges of using VR to improve karate performance. Based on the description above, the author proposes research questions such as (1) how VR technology can support the karate training process in improving performance, (2) what are the challenges faced in implementing VR to optimize karate performance, (3) how effective is the implementation of VR compared to conventional training in supporting karate performance, and (4) what is the future potential of VR for the development of karate training methods. This study is likely intended to assist academics, particularly those involved in the sport of karate, in better tracking the development of virtual reality.

Materials and Methods

Study Design

The type of research is a scoping literature review. This is similar to a systematic review, but the distinction is that it asks larger research questions to investigate existing information (Munn et al., 2018). Scoping literature review attempts to study the notion of literature methodically, using a rigid approach, to obtain synthesis and relevant information for future research (Munn et al., 2018).

Eligibility Criteria

The inclusion criteria in this study are as follows: (1) original articles and relevant literature reviews, proceedings from 2019-2025, (2) full text available for download, (3) Written in English, and (4) from Google Scholar, Wiley, Scopus, or Springer. Exclusion criteria include (1) not being published between 2019 and 2025, (3) Not written in English, (4) not being included in the Scopus, Google Scholar, Wiley, or Springer databases, and (5) incomplete text.

Procedures

This research is conducted using a systematic procedure, which is as follows:

- Conduct an observational study and analyze documents in the form of articles to define the research's theme, topic, title, and urgency.
- Determining research questions to focus the discussion so as not to broaden.
- Searching for related publications in the Google Scholar, Wiley, Scopus, and Springer databases using the Boolean keywords "karate" and "virtual reality" or "VR". This approach yielded 77 articles from a Google Scholar search, 27 from Wiley, 52 from Scopus, and 47 from Springer.
- The discovered data is evaluated to find duplicate articles and the relevancy of the articles to a total of 150.
- The articles are filtered again, yielding 25 articles.
- The next stage is to filter for articles that can be downloaded in full, which yields 9 articles.
- Following the team's agreement, the final analysis was conducted, and 9 articles were determined to be eligible.

To clarify, the Preferred Reporting Items for Systematic Reviews (PRISMA) analysis is shown below:

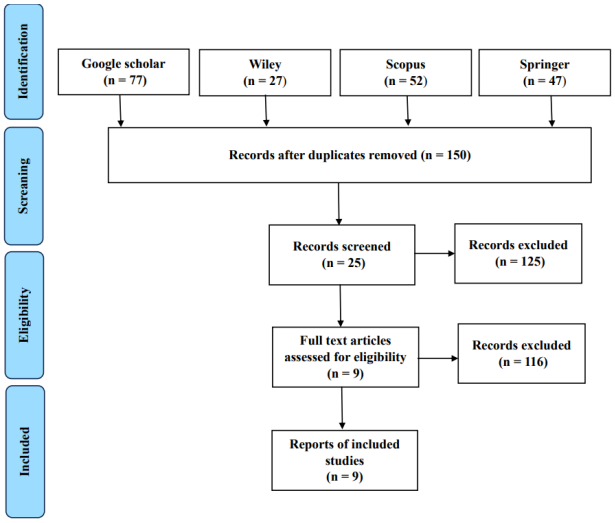

Fig. 1. PRISMA Flowchart of the Research Process

Data analysis

The published or published applications, Mendeley, Google Scholar database, Wiley, Scopus, and Springer all help with data collection and filtering techniques (Hafidz et al., 2024). Data analysis techniques are carried out by extracting meaning to understand how technology affects karate performance (Yudhistira et al., 2023). It was followed by compiling a narrative that can describe the results of the data information.

Results

Description of the review results based on selected articles through PRISMA analysis.

According to the results of the review analysis, 9 articles were identified as final data. The results of the analysis as a whole explain the development of virtual reality applications as applications to improve performance in terms of physical, technical, and motor skills in beginner, intermediate, and professional karateka, from the results of the 9 articles using experimental, non-experimental methods, concept development, and literature review (Ghazi et al., 2025; Lygouras & Tsinakos, 2024; S Pastel et al., 2023; K Petri, Bandow, & Masik, 2019; K Petri, Emmermacher, Danneberg, et al., 2019; K Petri, Timmerevers, Luxemburg, et al., 2019; Katharina Petri, Masik, Danneberg, et al., 2019; Ritter et al., 2022; Witte et al., 2022).

Discussion

RQ1: How can VR technology support the karate training process in improving performance?

The first argument is that VR is being used to improve the ability to respond quickly and anticipate punches and kicks. Karateka can improve anticipation by detecting attack patterns from the start of an action. According to Petri et al.,

Table 1. Summary of results from the review analysis of 9 documents

No	Author	Objective	Method	Population	Findings	Conclusion
1	(K Petri, Timmerevers, Luxemburg, et al., 2019)	Understanding the potential of VR applications as a learning tool for movement in karate	Experiments with pilot study design	Young karate athletes consisting of 7 women and 11 men	A significant increase was found in the execution of movements in the virtual reality group, and the video group, but not in the control group.	VR applications are ideal for both observational learning and improving physical ability.
2	(K Petri, Emmermacher, Danneberg, et al., 2019)	Understanding whether VR-based training can enhance reaction actions in techniques.	Experiment	15 experienced young karate athletes	Significant effects were found in terms of response time and quality of the VR group.	It was concluded that training with VR was beneficial for improving response actions in young karate athletes.
3	(Katharina Petri, Masik, Danneberg, et al., 2019)	Determining the effect of ten sessions of VR training on response actions and decision-making.	Experiment	15 experienced young karate athletes	The Friedman test results revealed that VR training greatly boosted karate-specific response behavior (as measured by motion analysis). The control group exhibited an increase with a small effect.	Training with VR is effective in enhancing sport-specific responses for young karate athletes.
4	(K Petri, Bandow, & Masik, 2019)	Understanding the impact of VR training on managing virtual opponent attacks	Experiment	15 experienced young karate athletes	Significant effects were found for time and time x group interactions for gyaku-zuki and kizami-zuki and found a time x reaction time effect in gyaku-zuki, but no significant time x reaction time effect for either attack. Paired t-tests showed significant effects for both pretest and posttest results.	These findings can be used to enhance motor learning in beginners to improve performance.

Table 1 (continued)

5	(Ritter et al., 2022)	Understanding the difference in response time and response type between real-time and virtual reality conditions	Non-Experiment	Experienced karate athletes consist of 17 men and 10 women	The results showed that there was no significant difference in response time and response type in virtual reality and the real world. Only the response quality was rated better in the real world.	It was concluded that the response time and response type for kumite category karate athletes in virtual reality conditions were similar to real-world conditions.
6	(Witte et al., 2022)	Understanding the difference between VR and the world in karate training	Experiment	17 male and 10 female karate athletes with international and national competitive levels	The findings revealed that the VR group had a longer response time to the gyakutzuki and kizamitzuki strokes. However, the response quality parameters for both groups did not improve. Athletes provided excellent feedback on the incorporation of VR training into conventional training.	It was determined that karate athletes who underwent VR training had better response times. The assumption that VR training can be applied in real-world scenarios cannot be demonstrated. There is evidence that VR training is effective for intermediate athletes. In the future, VR training tools should include freely engaging opponents.
7	(S Pastel et al., 2023)	Find out how VR compares to video training on the soto uke method that advances with the Zenkutsu Dachi posture.	Experiment	Male and female karate athletes totaling 83.	Results showed that VR was as effective as video training, and the transfer of VR-adapted skills in natural environments was equally adequate.	It is found that VR is an appropriate application for beginning athletes. The benefits of VR have yet to be completely shown, which is why the performance results are similar to those of other groups. As a result, further study is required to advance virtual reality.
8	(Lygouras & Tsinakos, 2024)	The goal of VR is to create a realistic training environment, evaluate performance, and enhance the development of technical skills.	Scoping review	Synthesis of the article consists of 7 documents.	Immersive technology, especially VR, offers the ability to record and capture precise movements that provide detailed feedback on reaction time, technique, and decision-making. This requires athletes and coaches to identify areas for improvement and adjust training based on the data.	It is concluded that, while immersive technology has a good influence, there are currently no clear frameworks or rules for its proper deployment in karate training. Thus, best practices and guidelines are required to enable optimal integration.
9	(Ghazi et al., 2025)	Exploring VR and AI applications to enhance karate performance	Descriptive exploratory	Concept development with several relevant articles	The primary papers discovered were (1) producing a meaningful and intuitive body movement-based self-image presentation to optimize practice, and (2) developing an efficient and professional model.	The application of VR and AI in karate training greatly enhances technique precision, movement efficiency, motivation, and feedback, resulting in fewer injuries. More research is expected to improve the technology's accuracy and efficiency, integrate virtual and real-world training, and ensure player safety.

installing the VR application can determine the response in the early stages of an attack by assessing the opponent's reach and steps to strike (K Petri, Bandow, & Masik, 2019). VR has been widely regarded as a tool to aid athlete training. The technology simulates a real-world environment to improve response time and anticipation in a variety of match situations. This enables athletes to respond to visual and aural cues similar to those encountered in real-world circumstances. Other studies suggest that VR improves physical performance, concentration, and motivation; therefore, VR is frequently used in endurance sports such as running, rowing, and cycling (Neumann et al., 2017). Simulations in virtual environments can provide a degree of focus and feedback that influences (Neumann et al., 2017).

The second topic is about VR being a safe practice for karate athletes. VR implementation for athletes can practice simulation methods without the risk of injuries caused by physical touch (Ritter et al., 2022). Simulation in VR allows athletes to repeat moves without any physical impact, which allows them to enhance their talents safely. A diversified approach to match simulation enables the discovery of many sorts and fighting techniques, boosting each individual's adaptability and strategy. Furthermore, athletes can simulate various scenarios and prepare for problems that may arise in real competition (Witte et al., 2022). The VR technique may be used anywhere and at any time, allowing athletes to train on their schedule (Lygouras & Tsinakos, 2024). Technology advances, providing increasingly realistic and interactive experiences that promote athlete participation in training.

As a result, the usage of virtual reality has proven to be an effective exercise for improving reaction speed, response, and anticipation. Furthermore, it is a safe and adaptable strategy for athletes. As a coach, this technique provides a tool and exposure to new ways of optimizing training programs. Virtual reality allows athletes to learn important skills safely and effectively. As a result, the first research question can be answered: VR can be a significant component in sports training programs, particularly in the sport of karate.

RQ2: What are the challenges faced in implementing VR to optimize karate performance?

As a result, there are benefits and drawbacks to using virtual reality to help in training. Discussing the disadvantages, notably that karate martial arts require physical contact, particularly in the fighting category, so that training remains relevant when training in real-time, degrading the nature of karate itself. However, when addressing the benefits, it is important to note that in the present era, training models and infrastructure require a touch of technology to make training more efficient and successful using a VR approach. Similarly, sportsmen can use VR for simulation training that involves elements of strategy, reaction speed, and improvisation. In this situation, how might coaches use VR as an addition to real-time training, rather than a replacement, to help training and matches operate smoothly?

The first point is that, while VR is excellent for training techniques and tactics, it cannot completely replace conventional training. For example, strength training involving external loads is not available in VR, so training with VR cannot completely replace conventional training. Another physical constraint is that VR can not mimic normally built physical training, such as stamina and agility, which cannot be fully performed with VR.

The second point addresses costs and infrastructure. Although VR technology is becoming more inexpensive, deployment still requires a significant initial investment. Furthermore, certain dojos and athletes may not have access to hardware like VR headsets and sensors. Next, consider the limitations of direct technical training. That martial arts place a premium on precise movement and physical contact. Although VR gives excellent imagery modeling, tactical features such as touch when hitting a target are impossible to recreate using present technology. Furthermore, the level of authenticity in some VR training can limit direct experience, which is critical in outsmarting and reading opponents when close range, long range, and timing are all important in karate.

According to a study by Petri et al., several challenges indicate that the implementation of VR requires further development, including increased realism, content variation, and long-term testing, for VR to be an effective application (K Petri, Timmerevers, Luxemburg, et al., 2019). Other studies say that technical, methodological, and implementation obstacles must be overcome before VR may become a more integrated tool (K Petri, Emmermacher, Danneberg, et al., 2019). VR solely provides visual inputs and no additional sensory stimulation, such as sound or touch. This decreases the immersive experience and the relevance of training to real-world situations (K Petri, Masik, Danneberg, et al., 2019).

Numerous hurdles must be overcome for VR to be a useful tool in the sport of karate. However, future development must focus on precise approaches to achieve effective VR results, such as selecting material specialists who are competent professionals in their disciplines, such as technological experts, professional trainers, and karate scholars. This challenge has piqued the author's interest in further developing VR.

RQ3: How effective is VR implementation compared to conventional training in supporting karate performance?

Discussing effectiveness necessitates extensive testing. The essence of karate is a physical contact sport (Yudhistira, Siswantoyo, et al., 2021). As a result, each exercise undoubtedly includes real movement. However, VR is used as a complement in the sport of karate. VR outperforms video and control groups in terms of observational and motor learning (K Petri, Bandow, & Masik, 2019). This is related to the karate learning approach, whereas other research shows that VR training can help young karate athletes improve their fast response (K Petri, Emmermacher, Danneberg, et al., 2019). Interestingly, not only connected to physical, studies show that the use of training with VR delivers a motivating training experience, resulting in new and safe learning (K Petri, Masik, Danneberg, et al., 2019). Furthermore, another study found that the response time and type of response for karate athletes were equally good in VR and the real world (Ritter et al., 2022), which is consistent with other studies that found that VR was better than the control group for response time, but neither increased for response quality parameters (Witte et al., 2022). Furthermore, athletes reacted strongly to incorporating VR training into traditional training (K Petri, Masik, Danneberg, et al., 2019; Witte et al., 2022). Furthermore, VR training proved as effective as video training for skill development (S Pastel et al., 2023).

As a result, the use of VR in conjunction with real-world training benefits karate athletes. However, the testing was only partial in terms of response time and motor motions. Other factors, such as agility versus reactive, have not been evaluated. The sport of karate, particularly kumite, requires a high level of reactive agility (Yudhistira & Tomoliyus, 2020). Then, during VR testing, it focuses just on punching. Meanwhile, extremities like kicks have received little attention when it comes to VR applications. Karate athletes rely heavily on their legs. For example, as an athlete moves forward to approach an opponent and backward to avoid an opponent, the power of the leg muscles, as well as the speed and agility to move while kicking, are critical (Yudhistira, 2023).

Furthermore, while VR may be superior in certain ways, more complete testing is required, such as increasing the sample size, using a more complex technique, and controlling for gender and training level. Another study found that, while VR promises unique and established technology and frameworks, there is none for effective use in karate training (Lygouras & Tsinakos, 2024). In this instance, best practices and recommendations are required for optimal integration (Lygouras & Tsinakos, 2024). However, combining traditional training with the use of VR is the most effective way to improve karate performance.

RQ4: What is the potential of VR for the development of karate training methods in the future?

Virtual reality has huge potential to transform karate training methods and sports programming by stressing an engaging, safe, and efficient approach. According to Ghazali et al's study, further development research is needed to improve VR, namely in terms of accuracy and usefulness in karate instruction (Ghazi et al., 2024). Furthermore, enhancing the analysis of user movements allows for real-time feedback to guarantee the technique is correct (Ghazi et al., 2024). VR can grasp how to optimize and improve movement efficiency (Ghazi et al., 2024). Immersive VR can make training more enjoyable, leading to greater motivation (Ghazi et al., 2024).

This technology allows athletes to analyze and adjust training tactics, increase response time, and transfer abilities to karate in real-time (Lygouras & Tsinakos, 2024). High interest and motivation in VR training are indicators that it has great potential (S Pastel et al., 2023). The integration of cutting-edge technology enables coaches to track athletes' progress in real-time and provide immediate feedback. VR is more than just an application; it opens up possibilities for actual accessibility. Furthermore, technology can be used to help coaches and athletes perform better (K Petri, Emmermacher, Danneberg, et al., 2019). In this example, VR enables the creation of artificial but realistic circumstances to enhance and evaluate sports performance, making standards and manipulation impossible in reality (K Petri, Timmerevers, Luxemburg, et al., 2019).

In response, virtual reality has the potential to positively impact the development of better training methods. VR allows coaches to apply and develop experience in the field of technology, while players can obtain unique training experiences. The future potential of VR requires better regulation of guidelines. It is critical to set standards for the use of VR in karate instruction so that it may be broadly used. So far, existing VR criteria do not include specifications for athletes in the novice, cadet, junior, or senior categories. Then, VR has so far been shown to improve motor abilities and response speed. The rest is such as VR, whose use is now insufficient for physical training programs, technical training, and so on. As a result, additional work is required to provide a higher potential for the development of VR-based training models in the kata and kumite categories that are tailored to the level of training, technological requirements, and so on. If these advancements are implemented, VR in the future will be more engaging and pleasant. The opportunity to have a more in-depth and effective training experience will grow.

Conclusions

Based on the findings and discussions, it is determined that (1) VR is one of the effective applications to enhance karate training by providing a safe and flexible approach, (2) the challenges in improving VR are that it requires further development in increasing realism, content variation, creating clear guidelines and long-term testing so that VR becomes an effective application, (3) wisely combining conventional training with VR implementation is the best solution to improve karate performance, (4) VR has positive potential to develop better training methods. VR has to strengthen its guiding principles and usage standards so that it may be broadly adopted. Overall, VR is a complementing and useful training tool for improving karate performance, particularly for experienced athletes who need to perfect reflex actions and build strategies in simulations that can be implemented in real matches.

Acknowledgment

The authors would like to thank Surabaya State University for allowing permission to conduct this research. The authors also like to thank the research team for their assistance in gathering and presenting data, which made it possible for this study to be completed properly.

Conflict of Interest

All authors declare no conflict of interest.

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Роль віртуальної реальності щодо оптимізації результативності у карате: Огляд предметного поля

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 1 табл., 1 рис., 23 джерела

Мета дослідження. Мета цього дослідження полягала в проведенні огляду предметного поля щодо ролі віртуальної реальності (ВР) в оптимізації результативності у карате. Питання, що підлягали дослідженню, були такими: (1) як ВР

сприяла тренувальному процесу, (2) які труднощі виникали у процесі інтеграції ВР, (3) наскільки ефективною виявилася ВР з точки зору максимізації результативності, а також (4) з'ясування потенціалу ВР у розробці методів тренування з карате.

Матеріали та методи. В якості методу дослідження застосовано огляд предметного поля. Етапи дослідження передбачали: (1) визначення назви, (2) визначення питання дослідження та (3) пошук статей у наукометричних базах даних Scholar, Wiley, Scopus та Springer із використанням ключових слів, що містять логічний тип даних «карате» та «віртуальна реальність» або «ВР». У результаті пошуку публікацій було отримано матеріали із наукометиричних баз даних Google Scholar 77, Wiley 27, Scopus 52 і Springer 47. (4) Під час первинного відбору отримано 150 статей. (5) У підсумку повторного відбору отримано 25 статей, і (6) визначено остаточні дані, що дозволило отримати загалом 9 статей. Для збору та аналізу даних використовувалися такі методики, як Publish or Perish, Mendeley та наративна інтерпретація.

Результати. (1) Віртуальна реальність є однією з успішніших програм, що дозволяє покращити процес тренувань з карате, забезпечуючи безпечний та адаптований підхід. Однак, для досягнення більшої ефективності, вдосконалення ВР потребує подальших досліджень з метою підвищення реалістичності, варіативності контенту, чітких інструкцій та довготривалого тестування. (3) Поєднання традиційних тренувань і ВР виявилось найефективнішим методом підвищення результативності у карате. (4) Незважаючи на позитивний потенціал ВР, необхідно вдосконалити інструкції та стандарти використання, перш ніж впроваджувати зазначену технологію у широких масштабах.

Висновки. Отримані дані свідчать про те, що віртуальна реальність стає доповнюючою та ефективною програмою для проведення тренувань у контексті поліпшення показників результативності у карате.

Ключові слова: віртуальна реальність, оптимізація результативності, спортивна технологія, карате, огляд предметного поля.

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Cite this article as: Yudhistira, D., Fauzi, M. S., Naheria, N., Cahyono, D., Ramadhan, K., Bimantoro, A. P., Putra, S. H. P., Irawati, A. F., Mappanyukki, A. A., Rahman, A., & Jannah, A. M. (2025).The Role of Virtual Reality in Optimizing Karate Performance: Scoping Review. *Physical Education Theory and Methodology, 25*(2), 426-433. https://doi.org/10.17309/tmfv.2025.2.25

Received: 18.01.2025. Accepted: 18.02.2025. Published: 30.03.2025