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Review Article

Ascertaining the Evolution and Research Trends on Virtual Reality in Archery: A Bibliometric Analysis

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Abstract

Background. The development of VR archery technology provides easiness of the faced difficulties by giving real visualization and new experience for the users.

Objectives. The present study aimed to ascertain trends, evolution, research spread and research approach related to VR archery.

Materials and methods. A literature analysis was conducted using bibliometric analysis approach. Harzing's publish or perish, Mendeley desktop, and Vos viewer were applied in this present study. A total of 77 articles from 2015 to 2025 were identified in the Scopus database using the keywords "VR archery", "Archery Virtual Reality", and "Virtual Reality Archery". According to study, 42 articles were found to be duplicated, 3 articles were incomplete, and 2 articles were excluded on the basis that they were not relevant to the subject. The Vos viewer was employed to analyse a total of 30 articles. In the process of sample description, it was examined the number of annual published articles, yearly citation, and articles with the most citation. A bibliometric analysis revealed research evolution each year, influencing publication and research trend related to Virtual Archery.

Results. The results of co-author analysis, bibliographic coupling, keyword co-occurrence, and overlay visualization revealed collaboration among researchers, the relation among articles, and network spread forming a cluster. Furthermore, the obtained data provided detailed knowledge concerning the 11-year period of VR archery development, focusing on the formed cluster, significant publications, and collaboration network.

Conclusions. The findings of this study were beneficial for researchers in developing VR archery in the future and for research practitioners in facilitating to solve difficulties through VR technology.

Keywords: virtual reality, archery, archery education, sport performance, bibliometric analysis.

Introduction

The development of technology provided so many easiness for human to perform both their work and daily activity. Purchasing of thing or food could be done without face to face meeting through e-commerce. Interdisciplinary sharing of experts could be performed through network using virtual meeting application. The advanced development of technology also gave benefit in sport and education achievement (Huang & Yongquan, 2025). The use of technology in educational sports aimed at increasing student interest in the learning process in order to meet learning achievements (Roth et al., 2025). Meanwhile, in sports field, technology development was widely used in developing digital learning tools, digital analysis and evaluation, independent training applications, digital scores. The use of technology in competitive sports was used to develop components affecting sports performance and prevent injuries (Xu & Baghaei, 2025). The components influencing sports performance included bio motor, technical, tactical, and mental components (Bompa & Carrera, 2015).

The development of Virtual Reality (VR) technology had been widely discussed lately. VR was a technology allowing someone in an illustrated or simulated environment by creating a real/immersive experience (Ishida & Shimizu, 2023; Linne et al., 2024). This innovation was existing by the emergence of VR technology in several games (Sun &

Chai, 2025). VR technology was developed by several sports aiming at creating digital product which support the more accurate and efficient evaluation and training (Dal et al., 2024; Westmattelmann et al., 2025). VR technology was also developed in the process of rehabilitation, increased fitness, and increased life quality in the community (Lattré et al., 2025; Wang & Wang, 2025). Besides, VR technology was created to promote sport, education, independent evaluation, and to improve sport performance (Cao et al., 2025; Pastel et al., 2025; Zhu, 2025). The emergence of VR technology actually provided benefits in form of real experience and motivation for its users (Godoy Cumillaf et al., 2025).

The development of VR in archery was be carried out to overcome various difficulties by providing an immersive environment. Archery was one of the competitive sports competed in the Olympics. Before archery was included in a competitive sport, it was one of the cultural heritages in several countries from ancestors to be preserved. The previous studies showed that VR technology in archery could be used to improve athletes" skills and understanding (Richlan et al., 2023). The developed VR technology might also help youth to understand traditional archery as cultural heritage (Butnariu et al., 2018; Ishida & Shimizu, 2023). The present study analysed how far the VR archery development by analysing the dependent variables. The analysis was referred to the references having high influences and reliability, which was expected to reveal the developed VR archery. The description allowed the possible research gap, which could be studied further. In addition, the findings in the present study could be used as underlying theory in developing VR archery technology in the future.

Materials and Methods

The present study was literature study to know trends, evolution, research spread and research approach related to VR archery using bibliometric analysis. Bibliometric analysis was a literature study analysis used to find mapping, research gap, and research chances (Guntoro et al., 2024; Prasetyo et al., 2024). The analysis of the articles published in recent ten years taken from reliable data base allowed to result in underlying theory in the future research.

Data Source

Data base Scopus used in the present study. Articles included in the scopus database were believed to have high influences and got several reviews from the trusted reviewer team. The finding, therefore, from the database provided specific and deep information.

Data Selected and Analysis

To select articles, the writer used three applications, which were herzing publish or perish, Mendeley desktop, dan Vos viewer. Harzing publish or perish was used to sort articles based on the keywords, data base, article types, and publication year. Mendeley desktop was used for completing data and for eliminating irrelevant topics. In addition, Vos viewer was used for mapping research trends relating to the selected topics. The mapping was presented based on the writers, keywords and journals.

Procedure

The writer searched articles on the Scopus data base using harzing publish or perish application. The keywords used in searching were "VR archery", "Virtual Reality Archery", and Archery Virtual Reality". The time period in the system setting was research report published from 2015 to 2025. It was found 77 publications, in which the detail of "VR archery" was 22 publications, "Virtual Reality Archery" was 32 publications, and "Archery Virtual Reality" was 25 publications. The whole publications were then sorted using Mendeley desktop application. The basic of article sort were the suitability of the research topic, articles written in English, articles had complete component, and no duplication. The suitability of the research topic was when the article analysed VR in archery sport. After analysis, there found 47 articles eliminated due to similar or duplication of 42 articles, 3 publications with incomplete information, and 2 irrelevant articles. There were 30 articles eligible to analyse further.

30 eligible articles were then analysed using Vos viewer. Results of the analysis showed (1) Sample descriptions

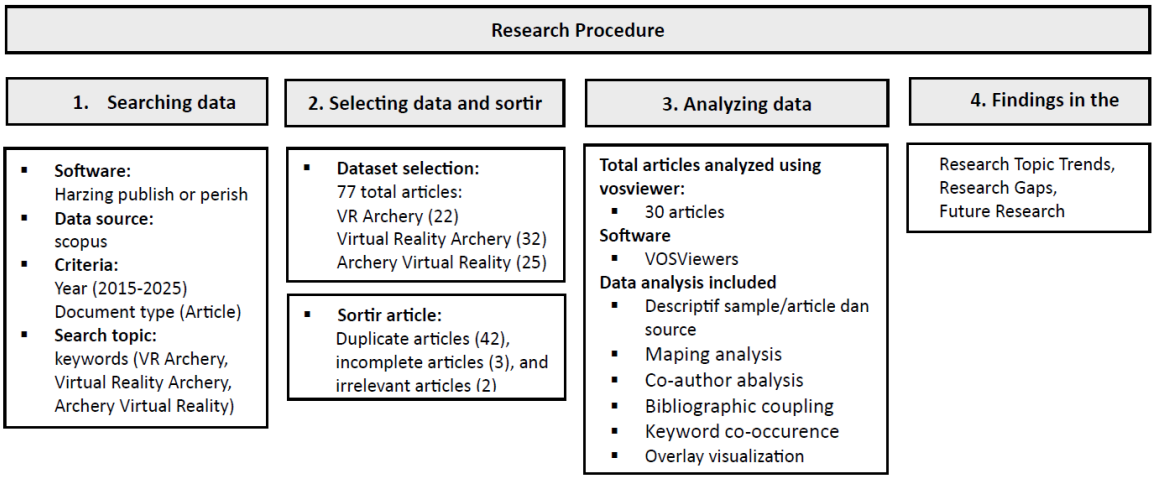

Fig. 1. Research procedure

containing publication number and citations each year and articles with the most citations. (2) Mapping analysis including co-author analysis, (3) Bibliographic coupling containing publisher ranking, keyword co-occurrence, clusters, and overlay visualization.

Results

The results of the bibliometric analysis describe the evolution of research each year, influential publications, and research trends related to Virtual Archer. In addition, the results of the study also describe the analysis of co-authors, bibliographic coupling, keyword co-occurrence, and overlay visualization describing collaboration between researchers, relationships between articles, and the distribution of networks that form clusters. A detailed description can be seen in the following sub-chapter.

Sample Description

Initial description of the publication sample with VR archery topics revealed collected publication development in one period. Figure 2 presents first period started from 2015 to 2020 and the second period started from 2021 to 2025. Research in first period in 2015 was started by the emergence of virtual technology development for rehabilitation process of stroke patients (Seo et al., 2016). The technology arranged to give patients easiness in rehabilitation process at home. VR games in former development was cooking game, archery, puzzle designed to improve patients' motivation for movement accessibility. Through time, the VR archery development was in form of games, training media for accurate training, to sensor use in VR archery (Adachi et al., 2020; Butnariu S et al., 2018; Park et al., 2017; Yasumoto & Teraoka, 2019).

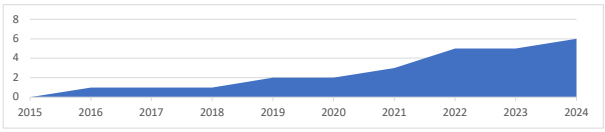

Fig. 2. Number publication per year

On the second period, it started from 2021 to 2025. Research in 2021 started to analyse VR technology developed to improve head and body coordination for children through virtual archery game (Esposito et al., 2021). In the further research, it needs to develop human interaction and drone-augment reality allowing them to browse virtually. The development can be fundamental aspect in developing tools for search and rescue of victims, monitoring plants, and inspection (Dorzhieva et al., 2022). For further research, VR archery development mostly focus on media development for training and its evaluation in improving the achievement (Dal et al., 2024; Richlan et al., 2023). However, VR archery development in the scope of introducing archery for community to improve interest and as education means is still performed (Nakamura & Ushida, 2024).

Figure 3 shows the citation number of articles each year. The peak of the citation was on the first period in 2016. The citation taken from the articles in 2016 was caused by little publication in this year. The researchers, therefore, cited that year articles as underlying theory in their researches. In the second period, the citation rate was increased as well as decreased. The decrease in citation number in the second period occurred in 2024. It was common in newly published research. While the high number of citations in the second period occurred because the documents in each year was quite large, so the resulting citations also tended to be higher. The citation number, however, obtained in the first period was still superior than citation number in the second period.

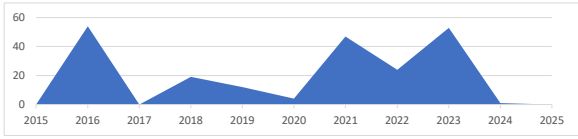

Fig. 3. Citation per year

Table 1 reveals the most cited articles of 30 articles analysed. Many citations were divided into two periods, in which the first period consisted of three articles belonging to most cited articles. It was due to the first period articles have been published in long time, causing more citation recorded. The article number on the first period was also less than the second period, causing writer had no more articles as references. The first period articles analysed the use of VR archery technology in rehabilitation, immersive VR simulator to give aiming opportunity, and VR to complete independent training by providing guidance and feedback (Butnariu S et al., 2018; Seo et al., 2016; Yeo et al., 2019). The most cited articles in second period consisted of two articles. Those articles analysed the impact of VR on sport performance, for example virtual reality-based imagery (VRBI) toward the aiming ability and imagery athlete (Bedir & Erhan, 2021; Richlan et al., 2023).

Table 1. Most cited publications

Publication Title	Authors	Year	Citations
Usability evaluation of low-cost virtual reality hand and arm rehabilitation games	Seo et al.	2016	54
Virtual training, real effects: a narrative review on sports performance enhancement through interventions in virtual reality	Richlan et al.	2023	44
The Effect of Virtual Reality Technology on the Imagery Skills and Performance of Target-Based Sports Athletes	Bedir & Erhan	2021	41
An interactive haptic system for experiencing traditional archery	Butnariu S et al.	2018	19
Augmented learning for sports using wearable head-worn and wrist-worn devices	Yeo et al.	2019	11

Maping analysis

Co-author analysis

Table 2 revealed the common citation number by most cited author. Result of analysis revealed ten categories of

author with highest link strength, in which the ten authors had same link strength, which was 6. The number of highest citations was Baza, Ahmed et.al who were an author group in an article having highest link strength, which was 10. It was continued by Kim, Taejun with document number of 2 and 10 citations and Ferrández-Vicente, José Manuel et.al with total citation of 2.

Table 2. Co-author analysis

Author	Publication year	Total link strength	Citations
Baza, Ahmed	1	6	10
Cabrera, Miguel Altamirano	1	6	10
Dorzhieva, Ekaterina	1	6	10
Fedoseev, Aleksey	1	6	10
Gupta, Ayush	1	6	10
Karmanova, Ekaterina	1	6	10
Kim, Taejun	2	6	8
Ferrández-Vicente, José Manuel	1	6	2
Gómez-Rodellar, Andrés	1	6	2
Gómez-Vilda, Pedro	1	6	2

Bibliographic coupling

Bibliographic coupling was used to look at the relation of document based on reference list. The bibliographic coupling analysis aimed at seeing the similar topic of the documents, to result in mapping. The mapping was useful for finding research gap for further research.

Table 3 illustrates the rank of 5 journals or conferences arranged based on the published articles and gotten citation concerning to the topic analysed which is "VR Archery". The table illustrates publication sites with widest spread. The most published journal was "Frontiers in Psychology" with two publications or documents and 85 citations. It is continued by "Journal of Rehabilitation Research and Development" with 1 publication/document and 54 citations. "Acta Polytechnica Hungarica" with 1 publication/document and 19 citations. "26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 – Proceedings" with 1 publication/document and 11 citations. Lastly, "Proceedings - 2022 IEEE International Symposium on Mixed and Augmented Reality, ISMAR 2022" with 1 publication/document and 10 citations.

Concerning to research related to "VR archery" was little analysed, the use of VR archery began to develop on the field of education, rehabilitation, psychology training, technical training and training to support sport achievement. Journal of "Frontiers in Psychology" became references mostly cited and had two documents. The document discussed about the efficacy of Virtual Reality Based Imagery (VRBI) to improve aiming ability and imagery skills of athletes (Bedir & Erhan, 2021). The second document analysed the previous study through literature study concerning VR in improving sport performance. Finding of the previous study showed that VR intervention had potentially real effect to improve sport performance through skill and psychological training including skills of actions, strategy, tactic, and decision making to respond to unpredictable events (Richlan et al., 2023). "Journal of Rehabilitation Research and Development" developed VR in form of archery game used for stroke patient rehabilitation program (Seo et al., 2016).

Table 3. Documents and citations per source

Source	Document	Citations
Frontiers in Psychology	2	85
Journal of Rehabilitation Research and Development	1	54
Acta Polytechnica Hungarica	1	19
Proceedings - 2022 IEEE International Symposium on Mixed and Augmented Reality, ISMAR 2022	1	10
26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 – Proceedings	1	11

"Acta Polytechnica Hungarica" published a document analysing the use of VR to improve human cognitive to understand mechanism of how ancient ow worked in archery sport (Butnariu S et al., 2018). 'Proceedings - 2022 IEEE International Symposium on Mixed and Augmented Reality, ISMAR 2022" published a document analysing drone-archery development through augmented reality (AR) human-drone to improve aiming skill (Dorzhieva et al., 2022). "26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019 – Proceedings" published a document developing tools to help people performing independent training and was completed with feedback given on several sports including archery (Yeo et al., 2019).

Keywords co-occurrence

Keywords co-occurrence was analysis used to know the keywords resulting in trend/pattern of research topics being analysed. This analysis also revealed relating topics studied through times. Figure 3 illustrates the co-occurrence of keywords which were often used by authors. The colour difference of each bullet illustrates the keyword groups that perhaps were cited together. The bullet size illustrates the keywords frequently used. The big bullet size illustrates the frequently used of the keywords, while the small size bullet illustrates the rarely used keywords. The narrow space between one bullet to another illustrates the keywords relationship. The narrow space between bullet described the high interest and allowed to take together, while the far space one described the low interest.

Figure 4 shows clearly the keyword of "virtual reality" accompanied by other keywords of "archery" and "archery game". Further exploration illustrates the cluster groups based on colour, in which the analysis result showed four cluster, which were brown, red, green and blue clusters.

Cluster I (brown) is called as "the development of virtual reality technology" consists of virtual reality, attentional control, eye tracking, mindfulness meditation, shooting, physical education, and archery game. The cluster presents publication about the development of the use of virtual reality technology in education, in preservation of

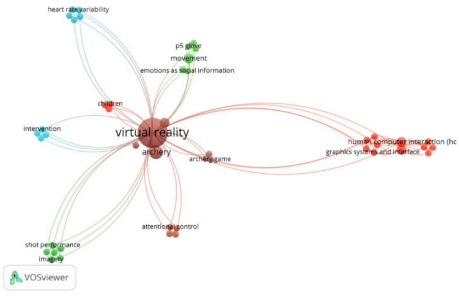

Fig. 4. keywords co-occurrence

traditional archery and in improving sport performance. Besides, the cluster also provided publication of collaboration use of sensor and virtual reality technology in improving performances in sport achievement.

Cluster II (red) is then called as "virtual reality assessment and Augmented reality (AR)" consists of computer interaction, mixed/augmented reality, head-trunk coordination, and children. The cluster presented publication about how virtual reality technology was developed to assess the coordination of head and body on children. Besides, this cluster provided Augmented reality (AR) human-drone developed to improve aiming and as base in developing tools for searching and rescuing as well as monitoring of farming in further research.

Cluster III (green) is then called "rehabilitation" consists of imagery, shoot performance, target spot, rehabilitation, stroke, and emotion as social information. The cluster showed independent training program by using virtual reality technology planned particularly for patients having stroke.

Cluster IV (blue) is then called as "virtual reality effect on psychology and psychophysiology" consisting of psychophysiology, vagal tone, virtual reality archery, intervention, performance, health rate variability. This cluster presented the difference of psychophysiological responses in the use of real archery and VR archery. The cluster also analysed virtual reality archery, which was beneficial on athletes' psychology in form of perception-action skill, strategy, tactic, decision making, unpredictable occurrence response, and in improving psychological defence under pressure.

Table 4. Co-occurrence of author keywords

No	Keyword	Occurrences	Total link strength	Citation
1	Virtual reality	18	71	168
2	Movement	2	13	56
3	Game	2	12	54
4	Human Computer Interaction (HCI)	2	12	11
5	Human-centered Computing	2	12	11
6	Archery	4	10	6
7	Finger	1	9	54
8	Hand	1	9	54
9	Kinect	1	9	54
10	Motion	1	9	54

Table 4 shows the keyword emergence frequency list, link strength, and total document. As illustrated in Figure 3, the keyword of "virtual reality" is the most frequent used keyword with frequency link strength of 18 and 71, subsequently. Then, it is followed by other keywords related to main keyword.

Figure 5 illustrates the development of research topic through time. The difference of colour each bullet shows topic analysis period. The dark colour shows research topic in the past, while the light colour shows newest research topic. VR archery game was past research topic focusing on rehabilitation program to train movement on patients with stroke. Through time, VR archery was developed to train motoric for children. The newest research on VR archery was the development of sport performance through tracking heart rate (physiology) to imagery training (psychology).

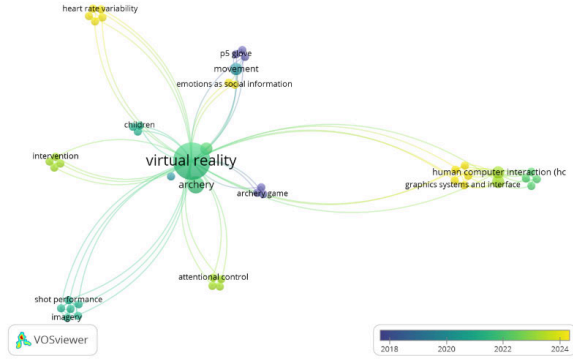

Fig. 5. Overlay visualization

Discussion

VR Archery was 3D game using Virtual Reality (VR) (Riwinoto & Harviando, 2023). The technology was displayed in real form to give real experience for users (Y. Shim et al., 2022; Y. A. Shim et al., 2022; Yasumoto & Teraoka, 2019). A mask or blindfold were used to show a live preview of the virtual environment which allows the user to feel in a real environment (Linne et al., 2024). Shooting-Based Technique (SBT) was a highly interactive VR archery movement method in virtual reality (VR) that allows the user to navigate through a simulated target-aiming action (Li & Takashio, 2023). The results of analysis illustrated that VR technology was used in preserving cultural heritage by depicting the operational visualization of traditional archery to improve students' understanding (Butnariu S et al., 2018; Dong & Yu, 2020). Kyudojo VR (training hall) and VR bows and arrows were developed identically to those used in real Kyudojo allowing users to have an immersive and realistic Kyudo experience (Ishida & Shimizu, 2023).

Besides, with the advanced continuous development of technology, the virtual reality (VR) technology was introduced in the field of physical education and it has been updated tools in innovative learning method (Jiang et al., 2024). The use of VR technology in teaching played an important role in increasing students' motivation in learning (Zhang, 2021). For example, the use of virtual reality as a means to monitor students' psychomotor skills (Palacios-

Alonso et al., 2022; Purnomo et al., 2022). VR development was used for independent learning and was equipped with feedback (Yeo et al., 2019). Feedback was an important component of the learning process that focuses on the results achieved (Krasovsky et al., 2024).

Result of analysis also revealed that VR archery could be used to improve sport performance. Intervention in VR had potential to cause real effect in improving sport performance through skill training and psychological aspect of athlete (Richlan et al., 2023). For example, the training of mindfulness during pre-competition period could improve focus (Gao & Zhang, 2023). VR as archery training tool helped in managing anxiety, difficulties, self-confidence, energy exposure speed felt (RPE), and shooting performance (Dal et al., 2024). Besides, the development of VR with AI is expected to assist the training evaluation process. The sport not only uses big data traditionally got but also virtual and added reality (Shin et al., 2024).

In wider use, the VR archery game was developed in a rehabilitation program for patients with stroke and in future research it is expected that it can be developed for patients with neurodegenerative disorders (Palacios-Alonso et al., 2022; Seo et al., 2016). VR archery was started to develop specially for blind people with the use of audio to give more experience for more users (Mendes et al., 2025). Then, to get more benefit in the future, the collaboration of VR and AR technology is expected to be applied in various parts, for instances in searching and rescuing, plant monitoring, inspection, and maintenance (Dorzhieva et al., 2022).

Implication and Further Research

The analysis of virtual reality in archery is little done during the decade. However, the bibliometric analysis been conducted provides several insights concerning to virtual reality development done by previous researchers. The finding of the present study, therefore, contributes in expanding knowledge of virtual reality in archery sport. Results of the initial description have outlined several topics that can be used as a basis for developing VR archery by considering several things. For example, topic relating to VR archery having potential to develop in the future, the reference availability, weakness and shortcomings of traditional methods with the use of VR in archery.

It entirely gives benefit for researcher to understand the variables relating to virtual reality and the theory. For example, to find underlying theory allowing VR archery in assisting rehabilitation process and psychomotor (Purnomo et al., 2022; Seo et al., 2016). Finding the underlying theory about the benefit of VR archery in developing psychology and physiology skill of athletes (Richlan et al., 2023). Finding and investigating the collaboration of several technologies like Virtual Reality (VR), Augmented Reality (AR) and sensor in improving performances in sport achievement (Adachi et al., 2020; Dorzhieva et al., 2022). It is also beneficial for practitioner. The research finding may enlarge the coach view point concerning the development of technology contributing the training process.

The findings in this study gives opportunities or gaps from previous research findings and become the basis for determining research topics related to VR archery in the future. First, the development of VR archery for independent rehabilitation processes in improving functional movement due to limited movement, stroke, sports injuries and neurodegenerative (Palacios-Alonso et al., 2022). The development of injury therapy and rehabilitation in the form of VR can increase motivation and provide new experiences for patients in the healing process. Second, the development of VR archery to train the movement coordination for beginner archery athlete. Third, the development of VR archery game, which can be used as promotion to improve community's interest toward archery sport. Fourth, the development of VR technology includes analysis of biomechanics, energy system, physiology, and psychology to improve archery athletes' performances. Fifth, the development of VR archery competition.

Conclusions

The research finding provides detailed knowledge concerning the period of VR archery development during 11-year period, the cluster formed as main field focus, big contribution publication, and collaboration network. Virtual Reality developed in archery sport in 11 years was VR archery for rehabilitation process, VR archery for coordination improvement, VR archery for learning, VR archery for improving sport performance, collaboration of VR, AR, and sensor technologies in sport achievement. VR technology which have been developed gave benefit for users and practitioner to fulfil their needs. The finding of the present study can be used by researcher as underlying theory in developing VR. The number of research relating to VR archery was still limited, so it has gap for further research.

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Conflict of Interest

The author has no conflict of interest.

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Визначення еволюції та дослідницьких тенденцій щодо застосування технології віртуальної реальності у стрільбі з лука: Бібліометричний аналіз

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

Реферат. Стаття: 9 с., 4 табл., 5 рис., 39 джерел.

Історія питання. Розвиток технологій віртуальної реальності у стрільбі з лука полегшує вирішення існуючих труднощів, надаючи користувачам реальну візуалізацію та новий досвід.

Мета дослідження. Мета цього дослідження полягала у визначенні тенденцій, еволюції, поширення досліджень та дослідницького підходу, пов'язаних зі стрільбою з лука у віртуальній реальності.

Матеріали та методи. Проведено аналіз літератури з використанням бібліометричного аналітичного підходу. У представленому дослідженні було застосовано програмне забезпечення Harzing's Publish or Perish, Mendeley desktop та Vos viewer. У наукометричній базі даних Scopus за допомогою ключових слів "VR archery", "Archery Virtual Reality" та "Virtual Reality Archery" встановлено загалом 77 статей за період з 2015 по 2025 рік. Згідно з дослідженням, виявлено 42 дубльовані статті, 3 статті були неповними, а 2 статті було виключено на підставі відсутності їхньої релевантності до предмета дослідження. За допомогою програмного забезпечення Vos viewer було проаналізовано загалом 30 статей. У процесі опису вибірки було досліджено кількість щорічно опублікованих статей, щорічну кількість цитувань та статті з максимальною кількістю цитувань. Бібліометричний аналіз виявив щорічну еволюцію досліджень, що впливає на публікації та тенденції досліджень, що стосуються галузі віртуальної стрільби з лука.

Результати. Результати застосування співавторського аналізу, методу бібліографічного сполучення, частоти спільної зустрічності ключових слів та візуалізації накладення дозволили виявити співпрацю між дослідниками, взаємозв'язки між статтями та поширення мережі, що утворює кластер. Крім того, отримані дані надали детальну інформацію щодо 11-річного періоду розвитку віртуальної реальності зі стрільби з лука, акцентуючи увагу на сформованому кластері, значущих публікаціях та мережі співпраці.

Висновки. Результати дослідження виявилися корисними для дослідників у подальшому розвитку віртуальної реальності зі стрільби з лука, а також для науковців-практиків у сприянні розв'язанню труднощів завдяки впровадженню технології віртуальної реальності.

Ключові слова: віртуальна реальність, стрільба з лука, навчання стрільбі з лука, спортивна результативність, бібліометричний аналіз.

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