ORIGINAL ARTICLE

Virtual reality in the performance of healthcare professionals

Realidad virtual en el desempeño del profesional de la salud

Diego A. Rivas-Vizcarrondo[1], Alejandra Sanchez-Villalon[1], Kento Ishii-Ynoue[1], Juan R. Mendoza-Carrillo[2], Jimena Estandia-Espinosa[3], Ariana Cerón-Apipilhuasco[4], and Jorge Loría-Castellanos[4]*

[1]Social Service, Universidad Anahuac; [2]General Coordination of the Residents Committee; [3]Coordination of the Pediatrics Committee. Red Nacional de Educadores en Simulación Clínica ; [4]Clinical Simulation Center. Universidad Anahuac. Mexico City, Mexico

Abstract

Background: *Virtual reality (VR) is an immersive technology of growing importance in medical education and clinical training. Objective: To analyze the available evidence on the impact of VR on the performance and training of healthcare professionals. Material and methods: A literature review (August 2025) was conducted in PubMed and Google Scholar, using the terms "virtual reality," "health," "simulation-based training," and "medical education." Results: The analyzed evidence shows that VR significantly improves cognitive, technical, and psychomotor skills in students and healthcare professionals. Several studies report increases in knowledge acquisition, reductions in procedure completion time, greater adherence to protocols, and increases in satisfaction and self-confidence. Conclusions: VR is an innovative and effective tool for continuing education and training in the healthcare field. Recent literature supports the notion that it matches or surpasses traditional methods across multiple educational indicators. However, the available evidence still exhibits methodological limitations across studies and a lack of data on its impact on long-term clinical outcomes, such as mortality and complication rates.*

Keywords: *Virtual reality. Health services. Simulation-based training. Medical education.*

Resumen

Antecedentes: *La realidad virtual (RV) es una tecnología inmersiva de creciente relevancia en la educación médica y la formación clínica.* **Objetivo:** *Analizar la evidencia disponible sobre el impacto de la RV en el desempeño y la formación de los profesionales de la salud. Material y métodos: Se realizó una revisión bibliográfica (agosto de 2025) en PubMed y Google Scholar, utilizando los términos «realidad virtual», «salud», «formación basada en simulación» y «educación médica».* **Resultados:** *La evidencia analizada muestra que la RV mejora significativamente las habilidades cognitivas, técnicas y psicomotoras en estudiantes y profesionales de la salud. Varios estudios informan de aumentos en la adquisición de conocimientos, reducciones en el tiempo de ejecución de procedimientos, mayor adherencia a los protocolos y aumentos en la satisfacción y la autoconfianza.* **Conclusiones:** *La RV es una herramienta innovadora y eficaz para la educación y la formación continuas en el ámbito de la salud. La literatura reciente respalda que iguala o supera a los métodos tradicionales en múltiples indicadores educativos. Sin embargo, la evidencia disponible aún presenta limitaciones metodológicas entre los estudios y escasez de datos sobre su impacto en los resultados clínicos a largo plazo, como las tasas de mortalidad y de complicaciones.*

Palabras clave: *Realidad virtual. Servicios de salud. Capacitación basada en simulación. Educación médica.*

***Correspondence:**
Diego A. Rivas-Vizcarrondo
E-mail: diegorivas02@gmail.com

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Introduction

Virtual reality (VR) is a computerized technological tool that allows users to interact with a three-dimensional environment in an immersive way. Its use has expanded across different areas, including the field of medical education, where it has grown significantly as an innovative method for the training and continuing education of healthcare professionals[1]. It is a subtype of extended reality, which encompasses any type of immersive technological experience, including augmented reality and mixed reality. Augmented reality superimposes computerized images onto a window of the physical environment in real time. On the other hand, mixed reality is based on the same principles as augmented reality, but the difference is that it allows the user to interact with the virtual elements projected onto the physical space[2].

VR is undoubtedly a practical, versatile, and increasingly accessible tool with a wide range of demonstrable benefits in different areas of the healthcare sector. Therefore, the aim is to highlight these benefits and promote its use in medical education and training.

The concept of VR originated in the 1960s, a period that saw the emergence of important figures in its development. Among them was Morton Heilig, creator of the three-dimensional Sensorama system, which provided one of the first immersive experiences by simulating a motorcycle ride with visual, auditory, olfactory, and tactile stimuli. Another notable figure is Ivan Sutherland, who introduced one of the first VR devices to include interactive graphics, laying the foundation for interaction with virtual environments. The first motion-tracking VR headset was created by Philco Corporation engineers Comeau and Bryan in 1961, representing a significant step toward integrating the user into the simulated environment[3]. Subsequently, its use spread to the United States Armed Forces, and in 1982, the Air Force developed the first flight simulator, in which the pilot, using a VR helmet, could control the trajectory within the simulation[3]. This simulator was developed thanks to the influence of Edwin Link, creator of the Link Trainer (or Blue Box) in 1929, the first commercially available flight simulator. This system allowed pilots to be trained by simulating realistic flight conditions without compromising their safety, while reducing training time and costs[4].

The first commercial devices began to appear in 1980. However, their true impact was felt a few years later, when that immersive experience of interaction and learning in contact with projected elements became useful for the benefit of people. Communities began to hear about how important this tool could become[3].

It was not until the 1990s that the use of commercial VR headsets spread to the field of healthcare, when certain odontologists began to place them on their patients during procedures to distract them with movies or video games, noting a considerable decrease in pain perception. At Children's Hospital in Seattle, Washington, it was used in a similar way with pediatric patients suffering from leukemia when they underwent painful procedures such as bone marrow aspirations, again demonstrating a decrease in pain perception. Therefore, one of the first functions of VR in the field of health was as a method of pain control, and subsequently, more research began to be developed on its usefulness and practical applications in different areas[5].

VR became a tool with different applications in the healthcare sector, combining interactive environments with elements of medical practice and other healthcare professionals. As a result of these initial studies of VR in healthcare, its use expanded, and new functions were developed. Essentially for training, such as in surgical simulation, in which preoperative planning and intraoperative guidance can be developed through the visualization of three-dimensional representations of surgical anatomical structures with the aim of obtaining specific approaches for each patient. In addition, physicians have gained practical experience through surgical simulation, perfecting their surgical skills, obtaining better results, and fewer complications. In neurosurgery, VR is used in the areas of spinal surgery, practicing minimally invasive approaches, in cranial surgery by creating personalized approaches for the resection of complex tumors, in neurovascular surgery by perfecting skills with a high level of dexterity, and in peripheral nerve surgery to practice complicated microsurgery procedures. At present, new technologies continue to be developed and applied in the practice of healthcare professionals[6].

Similarly, it is necessary to emphasize the importance of using VR for the development of different psychomotor skills. Greater evidence of these skills has been found in surgical areas or procedures, including eye-hand coordination, visuospatial perception, bimanual dexterity, fine and precise control of movements, automation of complex motor tasks, and economy of movement. The objective is based on achieving greater efficiency in procedures with less movement, making coordinated and appropriate use of both hands[7]. For example, SIMISGEST-VR, a training program in minimally invasive surgery, strengthens these skills in

various students, who must cauterize vessels, place surgical instruments in the correct location, move anatomical structures, among other tasks. The same system provides immediate feedback and encourages task repetition[8].

In the clinical setting, VR works on long-term skill retention, effective transfer to the real clinical environment, speed and accuracy in tasks, confidence in performing procedures, reduction of technical errors, and efficient motor planning and execution. For example, these concepts are explored in depth in many cardiopulmonary resuscitation (CPR) training programs, which offer real-time feedback on learning to place hands correctly, applying the right amount of force in chest compressions, and following the correct rhythm[9]. In other words, this tool is an opportunity to enhance all kinds of skills beyond those acquired in a classroom or clinical setting. Among the programs that facilitate such training are Health Scholars – CPR VR, Laerdal – CPR in VR/resuscitation training, SimX, Oxford Medical Simulation (OMS), and virtual medical coaching.

These systems have been implemented in medical education and represent a novel method to complement traditional teaching and training at both the undergraduate and graduate levels. As this technology advances and its use expands globally, its accessibility increases, and with it, the ease with which it can be implemented in educational systems, even in low- and middle-income countries. Its positive impact on the training of healthcare professionals, its versatility and adaptability, as well as its growing accessibility, make it an extremely useful tool for medical education today, and in the near future, it could become an essential resource within curricula and training programs[10].

Material and methods

A review article was written on VR in healthcare professional performance, with the aim of analyzing the available evidence on its impact and promoting its use as a tool for medical education and training.

The literature search was conducted in August 2025 in the PubMed and Google Scholar databases. Keywords such as “virtual reality,” “healthcare,” “simulation- based training,” and “medical education” were used, combined with operators such as “or” and “and.”

Articles in English or Spanish published between 2018 and 2025 were included, corresponding to systematic reviews, meta-analyses, and original articles related to the use of VR in the healthcare sector, with access to full text. Publications that addressed this topic outside the field of health and did not have access to the full text were excluded. Finally, 35 publications were selected that met the established inclusion criteria and were relevant to the objectives of the review.

Results

Steve Dann, CEO of medical realities, says of VR: “It was supposed to be the next big thing in the 1990s. However, the technology wasn’t up to it; it couldn’t do what our imagination wanted it to do.” The missing element was access to digital processing power, which is now available to a significant portion of the population[11]. At present, the benefits of its implementation are being studied both in professional medical practice and in the training of medical students. Kyaw et al. conducted a systematic review and meta-analysis of the impact of VR on health education, evaluating the effectiveness of this tool in terms of knowledge, cognitive skills, attitudes, and the degree of satisfaction of professionals and students. They used other simulation modalities (low- or high-fidelity simulators, traditional practice, face-to-face environments) against forms of VR that included immersive, semi-immersive, or desktop environments, with feedback and 3D interaction, where many of the interventions were performed on undergraduate students. It was determined that, compared to traditional methods and other forms of digital learning, VR shows a slight increase in knowledge and a moderate to considerable improvement in cognitive skills, while evidence regarding attitudes, satisfaction, cost-effectiveness, and clinical impact was inconclusive[12]. In a systematic review by Kim and Kim.[13], they concluded that VR in medical education is effective in improving the skills of professionals and students. However, their study showed that less immersive applications could be more effective in terms of knowledge acquisition than more immersive forms, as measured by the influence and mental overload of using fully immersive technology. Similarly, the phenomenon of cybersickness, which is often more severe when fully immersed, may further limit the effectiveness of highly immersive programs, which will be discussed in detail later. The latter differs from that described by Kyaw et al.[12], who report no significant differences in the degree of immersion. This study also reports a significant improvement in participants’ satisfaction with the experience of using VR as an educational tool. The findings coincide with the meta-analysis by Kyaw et al.[12], as both studies conclude that the implementation of virtual VR is effective in improving the cognitive skills

of students and healthcare professionals. Both studies also agree on the need for future research to focus on high-quality designs such as randomized controlled trials, long-term evaluation, and impact in real clinical settings, as well as the inclusion of measures such as cost-effectiveness and self-efficacy to provide sufficient evidence of its effect.

Current evidence supports the positive use of VR, contributing to the minimization of risks associated with clinical care and resulting in quality patient care[14]. Studies show that these practices improve clinical skills, promote patient safety, and lead to better patient outcomes compared to traditional learning methods. Among the indicators used are: knowledge acquired and knowledge retention (retention test), clinical or psychomotor skills (performance evaluation), compliance with protocols or safe practices, participant satisfaction, reduction of errors, and immediate feedback and structured debriefing[15].

This allows each user to improve the acquisition of technical skills, knowledge retention, confidence in performing procedures, precision in surgical tasks, or the development of deliberate practices focused on everyday procedures. Many programs have immediate feedback systems that allow students to improve efficiently. In addition, the repetitiveness that can be integrated into these practices allows professionals to function easily in the real medical environment. This approach is aimed at providing adequate healthcare with the least possible risk, improving patient safety[14]. Consequently, the use of simulation contributes to improving clinical outcomes for patients. Studies have shown that it leads to more accurate diagnoses, appropriate interventions, and effective management of medical emergencies. They did not directly evaluate mortality, hospital stay, or complication rates; however, they relied on the analysis of technical errors, adherence to protocols, decision-making, performance in emergencies, and clinical confidence to predict lower risks for the patient and how the improvement in outcomes looks[15].

These scenarios are generated in safe and controlled environments, so any error is a learning opportunity. Teamwork and interdisciplinary learning are essential elements of patient care. Simulation allows them to practice clinical scenarios in which they participate, promoting teamwork, communication, and respect. However, all these benefits depend on the degree of immersion and functional fidelity of the simulations. In contrast to traditional medical education, this results in a transcendental tool that takes quality in health care across great frontiers[14,15].

On the other hand, as VR development advances, we see more information about the benefits and advantages of using it, although there is less evidence of the side effects it can cause after exposure. In 1989, Baltzley et al.[16] conducted a study in which they analyzed and verified the concept of "simulator sickness," which consisted of dizziness, vomiting, and sleepiness after a flight simulation. In 1995, Kay Stanney used the term "cybersickness" to describe the adverse effects of VR use as one of its main problems[17,18].

It is defined as symptoms of discomfort during or after exposure to a VR environment, including headache, nausea, postural pain, disorientation, and instability, among others. An exact cause has not yet been defined; however, the most common is sensory conflict, an inadequate interaction between the visual, vestibular, and motor systems. That is, the mismatch between the movement that the user perceives visually and the absence of movement in the body[19,20].

Different scales can be used to classify cybersickness: the Pensacola motion sickness questionnaire, VR symptom questionnaire, and simulator sickness questionnaire. The latter, which is the most widely used, consists of 16 symptoms such as general discomfort, headache, diaphoresis, visual fatigue, vertigo, and dizziness, among others, grouped into three domains (nausea, oculomotor symptoms, and disorientation). The severity of each symptom is measured from 0 to 3, with 0 being absent, 1 mild, 2 moderate, and 3 severe. For each domain, a score between 5 and 10 indicates minimal symptoms, between 10 and 15 indicates significant symptoms, between 15 and 20 indicates worrisome symptoms, and more than 20 indicates severe symptoms. These results are used in a formula to obtain a total score, which can range from 0 to 235.62 points; higher values represent more severe alterations[18].

Consequently, one of the main limitations of VR in medical education is this phenomenon, as it becomes a barrier to acquiring knowledge. As it serves as a tool to improve theoretical and practical integration, if the user experiences this phenomenon, they are excluded from using this technology, losing the opportunity to acquire knowledge in this way[19]. Therefore, techniques should be applied to reduce this complication, such as program design, the time the user spends in the VR environment, taking breaks, among others. Studies suggest that around 55-70 min maximum may be appropriate when the software is of high quality, and the user is accustomed to the environment[13].

Another limitation is the financial barrier for health institutions and organizations with limited resources.

This is likely to be a short-term problem, as costs are becoming more affordable; however, it remains a significant expense. The acquisition of devices, maintenance, and updating of hardware and software over time must be considered[11,21]. It should be emphasized that, compared to purchasing a low-, medium-, or high-fidelity simulator, VR offers the advantage of significantly lower cost, no mechanical maintenance consumables, unlimited repetition, scalability for multiple users, portability, and automated feedback.

Despite today's high technology and these advantages, pre-existing technical limitations remain an obstacle. Accurate representation of real-life scenarios can be complicated, for example, the lack of realistic feedback or the absence of anatomical variations. Similarly, it is complex to accurately represent human behavior, both reactions and different characteristics among populations. Finally, in some cases, scenarios tend to be repetitive and very specific, with limited variations[21].

In the hospital sector, VR has made inroads into multiple medical specialties, but in some, it has had a greater impact and use. In the field of general surgery and minimally invasive surgery, there has been an improvement in psychomotor skills, such as coordination, precision, and bimanuality, and a reduction in surgical errors. Simulators such as SIMISGEST-VR allow different residents to practice surgical procedures such as cauterization and manipulation of the small intestine and colon without risk to patients[8].

In the field of cardiology, virtual simulation has been successfully used for anatomical recognition, clinical reasoning, ultrasound interpretation, and improved diagnostic accuracy in structural heart disease. Similarly, the incorporation of VR has complemented training in transthoracic ultrasound, a fundamental diagnostic tool in various areas of this specialty, allowing students and residents in training to develop and refine their skills before interacting with patients in real-world settings. Evidence shows that its impact lies in strengthening both technical and diagnostic competence, particularly in the acquisition, recognition, and interpretation of images. Similarly, it has been shown to increase confidence and safety when dealing with real patients, reduce errors in the early stages of training, and improve the integration of echocardiographic and clinical findings[22,23].

An example of how the use of VR has spread in medical training and has been adapted to different learning environments is the case of virtual medical learning, a Mexican company dedicated to the development of customized solutions for learning and practice in healthcare professionals and trainees. Its programs use applications, three-dimensional anatomical models, and practical VR scenarios with simulation and interactive experiences, which in the field of cardiology and anesthesiology allow for the practice of vascular access and echocardiography, reporting good results in terms of participant satisfaction and learning[24].

In anesthesiology, it has become very important for performing procedures with greater confidence and fewer risks, such as ultrasound-guided regional nerve blocks with VR. These procedures deepen anatomical understanding and technique, develop greater confidence, and allow maneuvers to be repeated without risk to the patient. It has been very innovative in growing and improving care, making the identification of structures in ultrasonography an everyday occurrence. This has led to this specialty being on track for the future of education for all healthcare professionals[25].

Likewise, in the area of critical care and intensive medicine, its impact has been strengthened in reducing anxiety, pain management, and cognitive distraction in mechanical ventilation or isolation[26]. Tasks have even been implemented for patients with chronic pain, where perception is modulated, and analgesic requirements are reduced. In neurology and neurorehabilitation, cognitive distraction and motor rehabilitation after cerebrovascular events are of great importance[11].

Similarly, VR has made many advances in the field of nursing, where various students have practiced chest compressions with immediate feedback, as well as intramuscular injections, device placement, and clinical scenarios, with greater confidence and precision[9]. As a result, this tool has been developed and used in multiple areas of healthcare. It is based on shifting traditional education to a primarily patient-centered approach, with a safe and interactive focus.

Today, there are several simulators that integrate VR. One of them, VirtaMed, consists of hybrid simulators for orthopedics, minimally invasive surgery, urology, and gynecology that improve technical skills and reduce surgical errors[27]. LapVR and LapSim, laparoscopic surgery training programs, increase precision and reduce operating time, where users manipulate real instruments that are reflected in a virtual environment[28]. OMS, for example, offers immersive VR clinical simulations for emergency scenarios, decision-making, and communication[29]. There is even a range of highly useful equipment in the field of nursing, which encompasses complex psychomotor skills[30].

Without a doubt, these simulators are highly innovative tools for enhancing their main objectives. Renowned companies in the field of health simulation, such as Laerdal, offer highly realistic and educational experiences by integrating VR into their simulators. One of their integrated platforms, SimX, allows students to interact with virtual patients in immersive and collaborative environments[31].

Some of the universities that have implemented VR in their curriculum include the University of Northampton, which has VR in a simulation room for nursing students. The University of Oxford implemented a mobile system to transport VR equipment at John Radcliffe Hospital[32]. At Saarland University in Germany, the support for its integration into its medical education program was evaluated with 252 students. The study showed 95.2% support for the use of VR in both clinical and preclinical areas[33]. As in these cases, there are numerous additional examples around the world, demonstrating the constant growth of the implementation of this technology in official curriculum programs[32].

Regarding the use of VR as an assessment method, the systematic review by Neher et al. analyzed 26 studies to determine the usefulness of immersive VR as an assessment tool for undergraduate medical and nursing students. Although this use is still under development, it demonstrated the potential for automating assessment in different areas of health education. Such is the example of clinical assessments such as objective structured clinical examinations, where its advantage lies in reducing the burden on the examiner, as well as in the potential to improve the objectivity and standardization of assessment. To maximize its usefulness in educational assessment, VR tests must be aligned with established teaching objectives and methods, without neglecting the necessary interaction between teacher and student[34].

Discussion

The current review shows that VR has established itself as a learning method and a tool to be used during the training of health professionals. Various studies demonstrate the positive impact of VR on the professional development of doctors and nurses, contributing to improved quality of patient care. Depending on its use, clinical and technical skills have been improved, achieving better results compared to other traditional learning methods.

Based on the evidence gathered from multiple systematic reviews and meta-analyses, this assertion is confirmed, as improvements were reported in the areas of knowledge, technical and psychomotor skills, and in the level of confidence and perception of satisfaction among the populations studied. In the meta-analysis by Sung et al.[1], data were taken from 45 randomized controlled trials, which showed positive effects in the areas of knowledge (standardized mean difference [SMD]: 0.28; 95% confidence interval [CI] 0.18-0.39, $p < 0.001$), skills (SMD: 0.23; 0.11-0.34, $p < 0.001$), decrease in execution time (SMD: −0.59; −0.82 to −0.35, $p < 0.001$), degree of satisfaction (SMD: 0.65; 0.48-0.81, $p < 0.001$), and confidence level (SMD: 0.60; 0.41-0.80, $p < 0.001$).

Its usefulness is not limited solely to the field of medicine. In nursing, the meta-analysis and systematic review by Lin et al. demonstrated a similarly positive impact on knowledge acquisition (SMD: 0.237, 95% CI 0.054-0.421, $p = 0.011$), skills (SMD: 0.682; 0.299-1.064, $p < 0.001$), confidence (SMD: 0.287; 0.008-0.567, $p = 0.044$), and satisfaction (SMD: 0.458; 0.256-0.661, $p < 0.001$)[30]. Another study focusing on nursing students also showed positive results in knowledge (SMD: 0.24; 95% CI 0.01-0.46), $p < 0.04$, and self-confidence (SMD: 0.40; 0.16-0.64, $p < 0.001$)[29].

In contrast to the findings of these studies, previous reviews demonstrated improvement in knowledge acquisition; however, they reported heterogeneous, inconsistent, and inconclusive findings regarding other outcomes such as improvement in practical skills, confidence, and satisfaction[9,10,12]. This suggests a maturation in the pedagogical methods used with VR, as well as an increase in the quantity and quality of studies developed on the subject in recent years, as suggested by recent reviews and meta-analyses[2,21,30] that have included a greater volume of randomized controlled trials, demonstrating recent growth in the development of quality studies, and which have allowed for better evidence of the effects in different areas of importance.

Despite these findings, the available evidence still has certain shortcomings, such as the validity of the results due to the different application scenarios between each study, along with their degrees of immersion and the fidelity of the simulations. For example, Kim and Kim[13] demonstrated in their study that less immersive applications could be more effective in terms of knowledge acquisition than more immersive forms. The latter differs from that described by Kyaw et al.[12], who report no significant differences in the degree of immersion.

Another shortcoming is that most studies are based on specialties that require technical skills, such as surgery, so several disciplines based primarily on clinical

practice and communication, such as internal medicine or psychiatry, have been less studied. However, in cardiology, anesthesiology, critical care, and intensive medicine, this tool has greatly benefited students, residents, and specialists, allowing procedures to be performed with greater confidence and fewer risks. It has even made great strides in the field of nursing.

Another limitation is publication bias, where studies with positive results tend to be found, so the benefits of VR may be overestimated. More research is needed on the disadvantages, notably the phenomenon of cybersickness, to better understand the real complications that a participant may experience when exposed to long periods of time or tasks in this area.

Future research should focus on high-quality studies that demonstrate the long-term impact of VR on clinical performance. As this is a recently developed technology, we need to understand its future effects and observe whether the aforementioned benefits remain significant over time. Kyaw et al.[12], through a meta-analysis, conclude that more studies, such as randomized controlled trials, should be conducted to evaluate the long-term impact of VR in real clinical settings in order to have sufficient evidence of its effect[13].

Similarly, most of the studies analyzed have focused on physicians, nurses, and students of these disciplines as participants. However, there are few studies that include other health professionals such as odontologists, psychologists, or pharmacists, who could also benefit from the integration of VR into their training and practice. Therefore, we encourage research into this technology in these areas, with the aim of expanding the available evidence in the healthcare field.

It is also essential to investigate the cost-benefit ratio of using VR in the development of healthcare professionals. It is true that this tool offers significant advantages; however, its implementation may be limited by acquisition and maintenance costs. Therefore, the feasibility of using VR as a learning tool becomes relevant for institutions with limited resources.

Finally, as a future line of research, the ethical aspects involved in the use of VR in education and as a learning tool should be studied for subsequent direct application to people. It is important to analyze issues such as the bioethical principles involved, data privacy and security, and the responsible use of this tool.

Conclusion

The evidence analyzed shows that VR is an innovative and effective tool for the training and continuing development of healthcare professionals. Its application ranges from undergraduate to continuing education, as well as in multiple disciplines such as surgery, cardiology, anesthesiology, critical care, and nursing. In these fields, VR has shown a positive impact on knowledge acquisition, improved clinical reasoning, the development of technical and psychomotor skills, and increased confidence and satisfaction among participants, indirectly contributing to safer and higher-quality care for patients.

Furthermore, the systematic reviews and meta-analyses included in this study agree that VR surpasses or at least equals traditional methods and other simulation modalities in terms of knowledge indicators, clinical task performance, execution time, protocol adherence, satisfaction, and self-confidence. The opportunity to practice repeatedly in controlled environments, without risk to real patients, with immediate feedback and objective goals, makes this tool a highly valuable resource for training, decision-making, and preparation prior to contact with the real medical environment.

However, this review also highlights critical points to consider for proper implementation. Limitations persist in the quality and homogeneity of the evidence, with many studies being short-term, with variable immersion scenarios, and focusing on surgical specialties, leaving clinical areas less explored. In addition, the results are mainly based on educational and performance indicators, with little data on “hard” clinical outcomes such as mortality, complications, or hospital stay. Furthermore, there is publication bias and limited evaluation of adverse effects such as cybersickness, whose mechanisms, prevalence, and prevention strategies require further study.

From a practical standpoint, VR faces challenges related to acquisition and maintenance costs, technical limitations in accurately reproducing anatomical variability and human behavior, and the risk of reducing formative interactions between teachers and students if used in isolation. Therefore, emphasis is placed on integrating VR as a complement within well-structured curricula, aligned with clear educational objectives.

Finally, there is a need for future research to evaluate the long-term impact of VR on actual clinical performance, its cost-benefit ratio in different contexts, including resource-limited settings, its applicability in other health professions, and the ethical implications of its use. Considering its proven benefits and remaining challenges, VR is a tool with high potential to transform health education. Its careful, critical, and evidence-based incorporation will allow its advantages to

be maximized, minimizing risks and ensuring that its implementation translates into better patient care.

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Conflicts of interest

J. Loría-Castellanos is member of the editorial committee of the journal *Anales Médicos*. The other authors declare no conflicts of interest.

Ethical considerations

Protection of human subjects and animals. The authors declare that no experiments on humans or animals were performed for this research.

Confidentiality, informed consent, and ethical approval. This study does not involve personal patient data, medical records, or biological samples, and does not require ethical approval. SAGER guidelines do not apply.

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