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Clinical Perceptions and Feasibility Analysis of a Virtual Reality Game for Post-Stroke Rehabilitation

Percepciones clínicas y análisis de factibilidad de un juego de realidad virtual para la rehabilitación Post-ACV

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Abstract

The increasing prevalence of strokes has led to the search for innovative rehabilitation methods. Immersive virtual reality (VR), especially personalized games, offers an interactive and motivating approach to therapy adherence. The perception and acceptance of physiotherapists are crucial to its implementation and require further investigation. The objective of this research was to evaluate the attitudes and perceptions of physiotherapists regarding the feasibility and effectiveness of a personalized VR game called *Motion Health VR* for post-stroke rehabilitation. The methodology employed consisted of using three strategies to collect subjective data. First, a multiple-choice questionnaire was administered to 73 physicians and physiatrists during the ISPRM 2023 Conference (International Society of Physical and Rehabilitation Medicine) to collect quantitative data on the utility and feasibility of *Motion Health VR*. Subsequently, a focus group was conducted with four physiotherapists to obtain qualitative information on the usability, accessibility, and cost-effectiveness of the game. Finally, a feasibility and cost-effectiveness analysis were performed to evaluate the possible long-term benefits and financial implications of implementing *Motion Health VR* in Colombia. The results obtained were a broad acceptance of VR as a complementary tool in post-stroke rehabilitation and the recognition of personalized games as motivators for patient participation. Physiotherapists highlighted the playability and immersion of the game, although they noted limitations related to costs and spasticity of the patient. The analysis indicated that initial costs, while significant, could be justified by long-term savings and improved patient outcomes. Finally, it is concluded that *Motion Health VR* demonstrated significant potential to complement post-stroke rehabilitation, receiving positive feedback from physiotherapists. Key challenges include improving access, reducing costs, and providing VR training to optimize rehabilitation outcomes.

Keywords

Cost-effectiveness, immersion, medical physiotherapists, motion health, spasticity.

Resumen

La creciente prevalencia de accidentes cerebrovasculares (ACV) ha impulsado la búsqueda de métodos de rehabilitación innovadores. La realidad virtual inmersiva (RV), especialmente los juegos personalizados, ofrece un enfoque interactivo y motivador para la adherencia a la terapia. La percepción y aceptación de los fisioterapeutas son cruciales para su implementación y requieren mayor investigación. El objetivo de esta investigación consistió en evaluar las actitudes y percepciones de los fisioterapeutas con respecto a la viabilidad y eficacia de un juego de realidad virtual personalizado llamado Motion Health VR para la rehabilitación posterior al ACV. La metodología empleada consistió en utilizar tres estrategias para recopilar datos subjetivos. Primero, se administró un cuestionario de opción múltiple a 73 médicos y fisiatras durante la Conferencia ISPRM 2023 (Sociedad Internacional de Medicina Física y de Rehabilitación) para obtener datos cuantitativos sobre la utilidad y viabilidad de Motion Health VR. Seguidamente, se realizó un grupo de discusión con 4 fisioterapeutas para obtener información cualitativa sobre la usabilidad, accesibilidad y rentabilidad del juego. Luego, se realizó un análisis de viabilidad y costo-efectividad para evaluar los posibles beneficios a largo plazo y las implicaciones financieras de la implementación de Motion Health VR en Colombia. Los resultados obtenidos fueron una amplia aceptación de la RV como herramienta complementaria en la rehabilitación post-ACV y el reconocimiento de los juegos personalizados como motivadores para la participación del paciente. Los fisioterapeutas destacaron su jugabilidad e inmersión, aunque señalaron limitaciones relacionadas con costos y espasticidad del paciente. El análisis indicó que los costos iniciales, aunque significativos, pueden justificarse por los ahorros a largo plazo y los mejores resultados para los pacientes. Finalmente, se concluye que Motion Health VR mostró un potencial significativo para complementar la rehabilitación post-ACV, siendo bien recibido por los fisioterapeutas. Los desafíos clave incluyen mejorar el acceso, reducir costos y brindar capacitación en RV para optimizar los resultados de rehabilitación.

Palabras clave

Rentabilidad, inmersión, fisioterapeutas médicos, salud del movimiento, espasticidad.

1. INTRODUCTION

Annually, more than 15 million people worldwide suffer a stroke, establishing it as the leading cause of acquired disability in developed countries [1]. Difficulty in using the upper limb is the most common post-stroke deficit, affecting over 70 % of survivors. However, less than 20 % achieve full functional recovery of their upper limbs, and more than half do not regain basic skills even after several years [2]-[3]. This situation highlights the need to prioritize improving upper limb recovery in post-stroke rehabilitation and related research [4].

In recent years, technology has begun to play a crucial role in rehabilitation, especially through virtual reality (VR). The integration of VR-based exercise games for post-stroke patient rehabilitation emerges as a promising innovation to change the traditional paradigm of physical recovery [5]. This technological advance, especially when implemented through user-centered design approaches, emphasizes creating personalized solutions that adapt to each patients' abilities, needs, and goals [6]. Active patient participation in the design process ensures that VR exergames (video games designed to promote physical activity and exercise) are not only accessible and stimulating but also relevant and engaging for them, thereby facilitating the safe and controlled practice of movement. Active patient participation in the design process ensures that VR exergames (video games designed to promote physical activity and exercise) are not only accessible and stimulating but also relevant and engaging for them, thereby facilitating the safe and controlled practice of movements crucial for effective upper limb recovery [5].

The use of VR allows greater personalization of exercises and provides a safe and controlled environment where patients can practice crucial movements for their recovery [7]. This technology can also record real-time data, facilitating the monitoring and adjustment of rehabilitation programs [8]. Despite these advances, there are significant barriers to adopting VR in rehabilitation, such as initial costs and the need for specialized training for physiotherapists [9]. Addressing these challenges is crucial to maximizing the impact of these technologies in clinical practice [10].

However, adopting VR systems in physical rehabilitation, particularly for older adults and other vulnerable groups, presents specific challenges [11]. This includes the need to design inclusive, accessible, and adaptive game content that fits these patients' limitations and contexts [12]. Clinical validation of these exergames by rehabilitation professionals is crucial for their effective integration into clinical practice, demonstrating their suitability for physical rehabilitation and promoting acceptance among medical staff, thus ensuring their clinical success [13].

Close collaboration between VR game designers, therapists, and patients is vital for developing technically advanced and therapeutically sound solutions [14]. This multidisciplinary synergy ensures that the playful aspects of exergames are seamlessly integrated with therapeutic goals, creating rehabilitation experiences that are both effective and rewarding [15]. These collective efforts underscore the importance of overcoming organizational and technical barriers in rehabilitation settings and reinforce the commitment to innovation in post-stroke disability treatment, promoting more motivating, personalized, and effective care for patients [16].

Despite these advances, there are significant barriers to adopting VR in rehabilitation, such as initial costs and the need for specialized training for physiotherapists [17]. Addressing these challenges is crucial to maximizing the impact of these technologies in clinical practice [18]. This article covers a preliminary feasibility evaluation of a custom-built VR game created for stroke rehabilitation involving therapists and clinical experts. We position our research within the context of enhancing accessibility and effectiveness of VR-based interventions, aiming to bridge the gap between technological advancements and practical implementation in rehabilitation settings.

2. RELATED WORK

The use of focus groups to evaluate the implementation of VR video games in post-stroke rehabilitation has provided crucial insights into the perceptions of medical specialists regarding this emerging technology. Several studies have investigated how rehabilitation specialists perceive VR, highlighting the relevance of qualitative methods to accurately capture the opinions and experiences of healthcare professionals [19],[20]. These studies have identified both significant opportunities and challenges for integrating VR into clinical practice, emphasizing the need to address concerns about costs and the adaptability of the technology to the individual needs of patients [21].

Moreover, several studies have investigated how VR exergames can complement traditional post-stroke rehabilitation therapies. For example, [22] patients who used VR exergames showed significantly improved upper limb coordination and strength compared to those who received traditional therapies.

Additional research employing focus group interviews with stroke survivors has provided complementary perspectives on how patients and professionals view the adoption of exergames for rehabilitation [23]. These studies have revealed that, while VR can be a motivating tool and enhance engagement with the rehabilitation process, its effective implementation requires careful consideration of the clinical environment specifics and the individual capacities of patients [24]. They have also demonstrated the importance of designing user experiences that are intuitive and accessible for different patient groups [25]. Despite the benefits, the adoption of VR in rehabilitation faces challenges. According to [26], one of the main obstacles is the initial cost of VR equipment and the need for specialized training for physiotherapists. These factors limit the accessibility and widespread use of this technology.

The psychological and motivational impact of VR has also been studied demonstrated that patients participating in VR-based rehabilitation sessions reported higher levels of motivation and adherence to rehabilitation programs, suggesting that the interactive and immersive nature of exergames can play a crucial role in recovery. Comparisons between conventional therapies and video game-based therapies, conducted through focus groups with therapists, have shown that VR can improve specific motor skills and offer a more dynamic and engaging rehabilitation experience [27]. However, these studies have also emphasized the importance of providing adequate training to healthcare professionals to ensure the efficient management of these technologies [28]. The combined analysis of these qualitative and quantitative approaches provides a comprehensive view of how VR video games can be adapted and personalized to optimize post-stroke rehabilitation outcomes while addressing the practical and operational challenges involved [25].

Collaboration between game designers, therapists, and patients is essential for developing effective exergames [15]. highlight that this multidisciplinary synergy allows for the creation of solutions that are not only technically advanced but also therapeutically sound and tailored to the specific needs of patients. Direct comparisons between VR and traditional therapies have shown promising results. A study by [5] found that VR was more effective in improving upper limb function compared to conventional exercises, due to its ability to offer real-time feedback and more precise personalization of exercises. Clinical validation of exergames is crucial for their acceptance and use in clinical settings.[29],[30] emphasize the importance of rigorous testing to demonstrate the efficacy of these programs and their integration into daily clinical practice.

Studies on the feasibility and cost-effectiveness of VR in post-stroke rehabilitation are also essential for its widespread adoption. Implementing VR systems involves significant initial costs, including devices, software, and staff training. However, in the long term, this investment can result in savings due to reduced therapy duration and improved patient outcomes. For example, [31], suggest that, although initial costs are high, the long-term benefits, both in terms of clinical outcomes and patient satisfaction, justify the investment. Additionally, strategies such as government grants, loan programs for medical equipment, and collaborations with technology companies can help mitigate these costs. Compared to traditional methods, which continuously require physical equipment and materials, VR could offer a more sustainable and attractive long-term solution [26].

The reduction in the need for physical materials and the possibility of conducting therapies remotely can also contribute to reducing operational costs [32]. A theoretical cost-benefit analysis suggests that, although the initial investment is high, the long-term benefits justify the cost [33]. Moreover, VR can improve patient adherence to treatment due to its interactive and immersive nature, which can lead to better functional outcomes and, therefore, a reduction in costs associated with long-term care and complications arising from incomplete recovery [25].

In the Latin American context, particularly in Colombia, the adoption of these technologies is still limited but growing. According to [34], intervention strategies in neurorehabilitation in Colombia have started to include the use of technologies such as VR, although scientific evidence and publications in this field are still limited. This article covers a preliminary feasibility evaluation of a custom-built VR game created for stroke rehabilitation, conducted within t-he Colombian healthcare context, highlighting the importance of considering the regions cultural and economic specifics for the successful implementation of these technologies.

3. METHODOLOGY

3.1 Motion Health: A Custom-Made VR for Stroke

The exergame "Motion Health VR" has been specially designed for the rehabilitation of patients after a stroke, immersing them in a virtual world where they perform cyclical movements with their upper limbs, such as elbow flexion and extension. These movements are inspired by rich Colombian traditions [35]. Initially, the game introduces activities that allow patients to become familiar with using their more able hands and progressively motivates players to use the hand with reduced mobility to perform exercises that benefit their recovery.

The game's difficulty can be manually adjusted by the researcher based on a visual assessment of the patient’s ability, offering a personalized experience that promotes muscle strengthening and improves dexterity in the affected areas of the upper limb using movements commonly recommended by physiotherapists in traditional therapies (see Figure 1). Patients are required to remain seated while using a standalone VR system, such as the Meta Quest 2, enabling full immersion and maximizing the therapeutic and entertainment potential of the game and the technology.

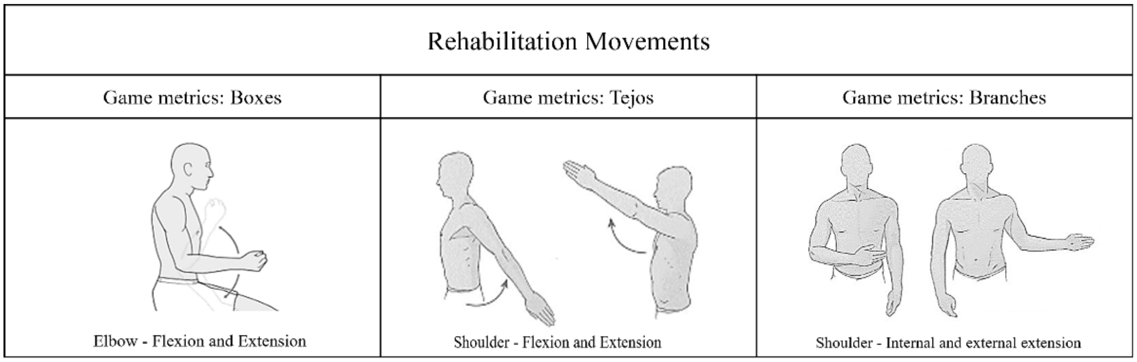

Figure 1. Cyclical Movements for physical rehabilitation performed in Motion health VR.
Source: own elaboration.

The exergame is developed through three key phases (see Figure 2). The first phase focuses on destroying boxes by hitting them, using elbow flexion and extension mechanics to encourage motor recovery (Figure 2A). The second phase introduces shoulder flexion and extension mechanics through a virtual tejo game, requiring controlled movements for precise throws (Figure 2B). The third phase incorporates more challenging movements by performing combined elbow and shoulder movements similar to Kabat diagonals, simulating the act of cutting branches while riding a virtual horse (Figure 2C). These activities aim not only to improve upper limb functionality but also to provide a culturally enriching experience, motivating patients on their recovery journey [36].

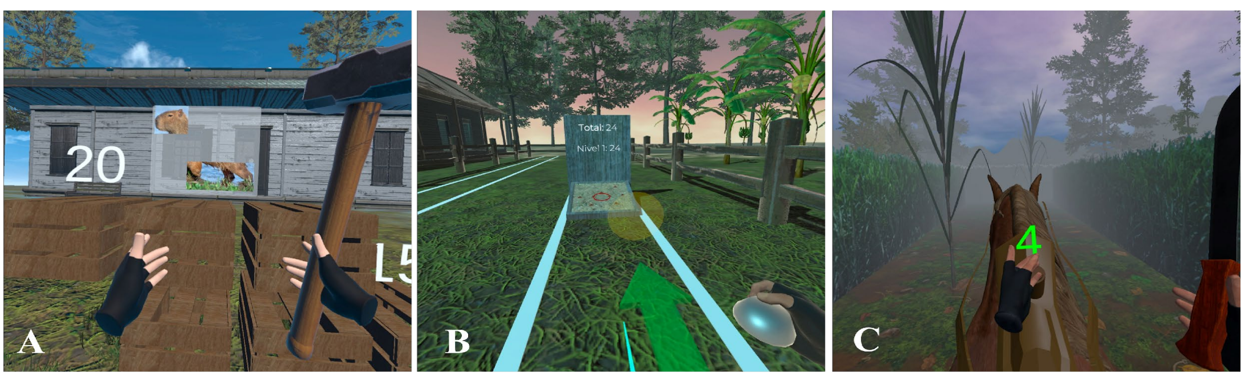

Figure. 2. Game Mechanics Motion Health VR- A Boxes; B Throwing Tejo; C Cutting branches.
Source: own elaboration.

3.2 Study Design

This study utilized a mixed design, structured into three main strategies:

- **Strategy 1: Descriptive Quantitative Evaluation**

In the first strategy, a descriptive and cross-sectional approach was chosen to evaluate the perceptions of medical specialists in physical and rehabilitation medicine, as well as general practitioners, through a survey on the utility and feasibility of the VR exergame Motion Health VR for post-stroke patient rehabilitation. This phase used a customized survey administered during the ISPRM 2023 conference in Cartagena, Colombia, leveraging the gathering of medical professionals from different regions of the world to capture a broad spectrum of opinions and experiences.

- **Strategy 2: Qualitative Evaluation via Focus Group**

The second strategy of the study used a focus group approach to explore the design and development considerations of Motion Health VR, specifically examining its applicability to the post-stroke population. Additionally, the advantages and disadvantages of the exergame were analyzed, and how it could be effectively integrated into existing physical rehabilitation programs. This approach provided a deeper understanding of the technical and practical aspects of implementing Motion Health VR in clinical settings, addressing the potential benefits and challenges of its use in post-stroke patient rehabilitation (Figure 3).

Figure. 3. Exergame tests carried out by physiotherapist at ISPRM 2023.
Source: own elaboration.

- **Strategy 3: Feasibility and Cost-Effectiveness Analysis**

In the third strategy, a feasibility and cost-effectiveness analysis were conducted in the Colombian context. This analysis included a cost evaluation, review of financing strategies, and a cost-benefit analysis. Motion Health VR was also compared with traditional therapies, the long-term economic impact was analyzed, and improvements for accessibility were proposed. Finally, a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted to identify key areas for improvement and potential challenges in implementing Motion Health VR in rehabilitation programs.

This combined study design provided a comprehensive view of the utility, feasibility, and challenges of implementing Motion Health VR in post-stroke patient rehabilitation, encompassing quantitative and qualitative perspectives.

3.2.1 Participants

- **Strategy 1: Survey at the ISPRM 2023 Conference**

The first strategy focused on collecting data during the ISPRM 2023 conference. 73 doctors, including 23 medical doctors practitioners and 50 physiatrist doctors, were interviewed to obtain diverse opinions on the application of Motion Health VR in physical rehabilitation. This diverse group of professionals provided a global perspective on the potential of VR exergames for rehabilitation. Considering the context of an international conference, the data were collected anonymously, avoiding demographic questions to keep the survey concise. It is noteworthy that, although not all respondents had the opportunity to interact directly with the exergame, a considerable portion could observe colleagues using it or watch demonstrative videos of patients in the study context.

- **Strategy 2: Focus Group with Physiotherapists**

The second strategy involved organizing a focus group with four physiotherapists from the Faculty of Medicine at the *Universidad Tecnológica de Pereira*, focusing on post-stroke rehabilitation. Physiotherapists, with over ten years of experience, hold various roles within the university and have private practices, providing a diverse perspective on rehabilitation. Additionally, one of them leads a rehabilitation group for older adults with strokes. Their experience spans from teaching to direct practice in kinesiology and physiotherapy. To recruit these physiotherapists, invitations were extended through the university and local rehabilitation centers, contacting a total of nine physiotherapists via email and phone calls. Only four could participate, reflecting the time constraints due to their professional obligations. This recruitment method aimed to ensure informed and committed participation despite the logistical challenges of coordinating with busy professionals.

- **Strategy 3: Feasibility and Cost-Effectiveness Analysis**

The third strategy included a feasibility and cost-effectiveness analysis in the Colombian context. To conduct this analysis, data were collected from various sources, including cost reports from rehabilitation clinics, interviews with health administrators, and analyses of national and international economic data [37]-[39]. No specific individual participants were recruited for this strategy; instead, secondary data and interviews with experts in financing and health service administration were used. These experts provided key information on the costs associated with implementing Motion Health VR in clinical settings, possible financing strategies, and the cost-benefit analysis compared to traditional therapies.

3.3 Instruments

- **Strategy 1: Customized Questionnaire**

For the first strategy, a customized multiple-choice questionnaire was developed to explore and gather opinions on Motion Health VR from professionals with significant experience in physical rehabilitation. This questionnaire, consisting of thirteen objective questions, aimed not only to collect favorable opinions and constructive criticism about the exergame but also to delve into various critical aspects related to its implementation.

The questions, such as “Would you use this type of development for the clients/patients you attend to in your practice?”, “How did you find the utility in terms of promoting physical exercise for individuals with stroke?”, “Do you consider that this type of virtual exercise or therapy has any kind of advantage?”, and “What do you think is the biggest challenge when using virtual reality in physical rehabilitation?”, were designed to cover a wide range of topics. These topics included evaluating its clinical utility and effectiveness, accessibility and associated costs, as well as the professional’s personal assessment of the efficacy of Motion Health VR and their willingness to recommend this tool to their patients.

This comprehensive approach aimed to obtain a holistic understanding of how health professionals perceive the integration of VR exergames within physical rehabilitation programs, identifying potential areas for improvement and validating product acceptance.

- **Strategy 2: Focus Group Session**

In the second strategy, a 90-minute interactive session was organized with four physiotherapists to explore in depth the advantages and disadvantages of Motion Health VR. During this meeting, the relevance of the activities proposed by the exergame, its integration into existing rehabilitation regimens, and the adaptability of its functions to the specific needs of post-stroke patients were discussed. This approach provided a detailed view of the physiotherapists perspectives regarding VR-assisted rehabilitation, similar to the results found in studies on managing musculoskeletal shoulder pain through immersive VR. Using a qualitative descriptive methodological design, focus group interviews were conducted to explore the beliefs and perspectives of physiotherapists, identifying possible barriers and facilitators. These findings offered valuable insights into the acceptance of immersive VR as a rehabilitation platform and highlighted the need for further research to address the questions raised by professionals.

- **Strategy 3: Feasibility and Cost-Effectiveness Analysis**

For the third strategy, several instruments were used to conduct the feasibility and cost-effectiveness analysis in the Colombian context. These instruments included:

Cost Reports Review: Cost reports from rehabilitation clinics were analyzed to obtain a detailed understanding of the current costs associated with physical rehabilitation.

Conversations with Health Administrators: Anecdotal conversations were held with health administrators, leveraging constant contact with them, to gather information on financing strategies and the economic viability of implementing Motion Health VR in clinical settings. These informal discussions provided valuable practical insights into the challenges and opportunities related to adopting this technology in the healthcare system.

Economic Data Analysis: National and international economic data were reviewed to compare the costs and benefits of Motion Health VR with traditional therapies.

SWOT Analysis: A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted to identify key areas for improvement and potential challenges in implementing Motion Health VR in rehabilitation programs.

These instruments allowed for a comprehensive analysis of the feasibility and cost-benefit ratio of Motion Health VR, providing a solid foundation for its potential implementation in the context of post-stroke rehabilitation in Colombia.

3.4 Procedure

- **Strategy 1: Survey**

Phase 1: Workshop During the Conference:

The first element of the study focused on examining in detail the perceptions of medical professionals regarding the incorporation of Motion Health VR into current treatment schemes for post-stroke rehabilitation. The objective was to highlight both the potential benefits of this VR exergame for physical rehabilitation and identify obstacles that could hinder its implementation, including economic and accessibility factors. The methodology was structured into two main phases to provide doctors with comprehensive experience, both theoretical and practical, in the use of this VR tool in rehabilitation.

This phase began with an informative and educational workshop session lasting over 2 hours, led by experts in VR and physical rehabilitation, titled "VR Exergames in Rehabilitation: Lessons Learned from a Multidisciplinary Team," and presented during the ISPRM conference. This presentation aimed to familiarize doctors with user-centered design, VR game design, and collaboration between clinical experts and engineers. During the workshop, demonstrations of the Motion Health VR system and videos showing stroke patients interacting with the system were presented. Attendees were invited to participate in the survey after the workshop concluded.

Phase 2: Immersive Demonstration at Stand

An interactive stand equipped with VR technology, including VR headsets and a real-time display screen, was set up at the conference. This space was available throughout the three days of the ISPRM 2023 conference. Medical and physiatrist doctors attending the conference were invited to participate in guided sessions to delve into the mechanics of Motion Health VR. These sessions allowed doctors to explore the various rehabilitation activities offered by the exergame under the supervision of a research team member. While one doctor interacted with the exergame (approximately 15 minutes in total), others could observe the experience in real-time through the screen, facilitating discussion, questions, and comments between the doctors and facilitators. During this process, they were invited to complete the survey at any time during or after the demonstration. Therefore, the multiple-choice questionnaire was emailed to doctors to collect their detailed evaluations of the experience, the clinical applicability of the exergame, and improvement suggestions. Some responded immediately, while others did so in the following days.

This dual approach not only allowed medical professionals to gain a deep understanding of Motion Health VR from both theoretical and practical perspectives but also facilitated the collection of valuable data on their perception, potential integration into physical rehabilitation, and areas for improvement. The combination of detailed presentations during the workshops, direct or indirect interaction with technology, and enriched discussion ensured a comprehensive and multifaceted evaluation of the tool.

- **Strategy 2: Focus Group**

Phase 1: Introduction and Demonstration

The objective of this strategy was to conduct a focus group with physiotherapists and rehabilitation specialists to discuss the perceptions of the Motion Health VR exergame for upper limb rehabilitation in stroke patients.

The session began with a detailed presentation on the development of Motion Health VR, emphasizing its user-centered design aspects and preliminary results with stroke patients. This phase aimed to provide physiotherapists with a comprehensive understanding of how the exergame was specifically designed to meet the rehabilitation needs of post-stroke patients. Subsequently, a video was shown in which a post-stroke patient interacted with Motion Health VR, offering a dual perspective of the experience: the video of the patient using the equipment and the VR view of the patient (i.e., what the patient saw). This segment allowed physiotherapists to observe the practical implementation of the exergame in a real rehabilitation context.

Phase 2: Discussion and Opinion Collection

A space was provided for physiotherapists to discuss the advantages and disadvantages of Motion Health VR, evaluating its usability, therapeutic approach, and the relevance of its activities for physical rehabilitation. The focus group questionnaire for physiotherapists centered on evaluating how Motion Health VR could be incorporated into post-stroke patient rehabilitation. Basic participant data were collected, and deeper insights into their initial impressions and the tools ease of use for older patients were sought. The questions addressed game elements that could motivate patients, the clarity of instructions, and the suitability of the games challenge levels. Additionally, the effectiveness of specific activities within the game for physical rehabilitation was explored.

The objective was also to understand if this exergame could be integrated into existing rehabilitation programs, how it compares with traditional methods, and whether physiotherapists would recommend it. The questions aimed to capture both positive aspects and potential challenges or limitations of using Motion Health VR in recovery treatment, allowing for an evaluation of its practical applicability in real contexts.

Physiotherapists were encouraged to share their opinions on the role of Motion Health VR in rehabilitation processes. Recommendations and suggestions were sought to improve the integration of this type of technology into the physical rehabilitation of post-stroke patients. Direct dialogue with physiotherapists generated a set of perceptions about the use of VR technology in physiotherapy. The discussion captured a wide range of opinions on the practical implementation of Motion Health VR in clinical settings. The methodology was designed to facilitate meaningful interaction between physiotherapists and Motion Health VR, combining theoretical aspects with practical experience. Through presentation, demonstration, and discussion, physiotherapists gained a detailed understanding of the exergame and its potential in post-stroke rehabilitation.

- **Strategy 3: Feasibility and Cost-Effectiveness Analysis**

Cost Evaluation: to carry out this strategy, information on the initial costs of acquiring VR devices, software, and staff training necessary to implement Motion Health VR in rehabilitation clinics was collected. These data were obtained through interviews with health administrators and reviews of financial reports from rehabilitation institutions.

Financing Strategies: several financing strategies were investigated to support the adoption of Motion Health VR. These included government grants, medical equipment loan programs, and collaborations with technology companies. Additionally, continuous training programs for physiotherapists were explored to ensure effective and safe implementation of the technology.

Cost-Benefit Analysis: a cost-benefit analysis was conducted comparing the costs associated with Motion Health VR and traditional therapies. This analysis included evaluating the expected benefits in terms of reduced therapy duration, improved clinical outcomes, and increased patient satisfaction.

Comparison with Traditional Therapies: the effectiveness and customization of Motion Health VR were compared with traditional therapies. The adaptability of Motion Health VR to the specific needs of each patient was evaluated to determine if it could improve treatment adherence and therapy effectiveness compared to traditional methods that require physical equipment and materials.

Long-Term Economic Impact: the long-term economic impact of implementing Motion Health VR in rehabilitation clinics was assessed. This analysis considered the reduction in operational costs due to the decreased need for physical materials and the possibility of conducting therapies remotely, as well as improvements in patients functional outcomes and the reduction of long-term costs associated with ongoing care and complications arising from incomplete recovery.

SWOT Analysis: a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted to identify key areas for improvement and potential challenges in implementing Motion Health VR in rehabilitation programs. This analysis helped establish strategies to maximize the exergames strengths and opportunities while mitigating potential weaknesses and threats.

Proposals to Improve Accessibility

Finally, proposals were developed to improve the accessibility of Motion Health VR. These included initiatives to reduce initial costs through specific financing programs for rehabilitation clinics, collaborations between the public and private sectors, and the provision of specialized training and continuous technical support for physiotherapists, ensuring a broader and more effective adoption of the technology.

4. RESULTS AND DISCUSSION

4.1 Strategy 1: Survey

The results obtained from the first strategy, which involved a survey directed at medical professionals during the ISPRM 2023 conference, provided valuable data on the perception and feasibility of integrating VR technologies, such as Motion Health VR, into rehabilitation treatments for patients who have suffered a stroke. This analysis focused on the responses and percentages of the respondents, with particular emphasis on four questions selected for their relevance, as shown in Figure 4. For a comprehensive exploration of all the questions posed in the survey, it is recommended to review Appendix 1, which includes the thirteen questions formulated.

Technological Innovation in Rehabilitation: A notable 91.8 % of the health professionals surveyed recognized the advantages that VR games like Motion Health VR present in the rehabilitation process (Figure 4). This high percentage indicates a significantly positive evaluation of VR technology as a therapeutic tool, suggesting a growing trend toward adopting innovative methods in the treatment and care of patients, particularly in the field of physical rehabilitation after a stroke.

VR as a Motivation and Engagement Tool: the survey revealed that 54.8 % of the respondents consider Motion Health VR motivating, while 45.2 % see it as an effective tool to promote physical exercise in individuals recovering from a stroke (Figure 4). These percentages reflect the perception of VR not only as a viable treatment modality but also as a means to enhance patients willingness to engage in physical exercise and rehabilitation. The incorporation of playful elements, a fundamental aspect of Motion Health VR, is seen as an essential strategy to make rehabilitation more appealing and varied for patients.

Challenges and Opportunities: despite the optimism towards VR technology, the study identified significant concerns regarding costs and accessibility, with 72.6 % of respondents citing these factors as potential barriers to the adoption of VR in rehabilitation practices (Figure 4). Additionally, the lack of familiarity with VR technology was mentioned by 63.9 % of patients, highlighting the need for educational and training strategies for both healthcare professionals and patients (Figure 4). These findings point to crucial challenges that must be addressed to facilitate broader integration of VR in clinical and rehabilitation settings.

Future of VR in Rehabilitation: The study concluded with a promising finding: 86.1 % of surveyed doctors expressed their willingness to use VR technologies like Motion Health VR in their clinical practice (Figure 4). This high degree of acceptance anticipates a future where VR could play a more central role in post-stroke rehabilitation, suggested by the willingness of medical professionals to explore and adopt these innovative technologies to improve rehabilitation outcomes.

This report, based on the survey responses and obtained percentages, underscores the positive reception of Motion Health VR among medical professionals and highlights both the potential and the challenges for integrating VR into post-stroke rehabilitation. While the technological innovation and motivational potential of VR are recognized, economic and training aspects emerge as critical areas that require attention to maximize the reach and effectiveness of these technologies in the healthcare sector.

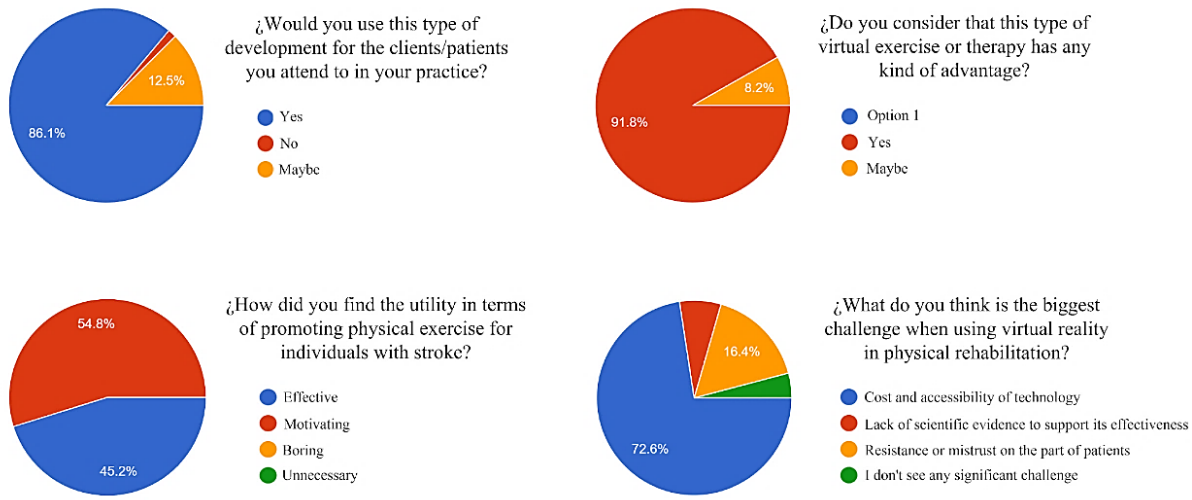

Figure 4. Four questions of the thirteen total applied in the survey for physiotherapists, with the answers in pie diagrams and their percentages. Source: own elaboration.

4.2 Strategy 2: Focus Group

Strategy 2, implemented through a focus group with four experienced physiotherapists, provided a comprehensive evaluation of Motion Health VR, highlighting its application in upper limb rehabilitation for patients who have suffered a stroke. This approach is broken down into five key subtopics that range from initial perceptions to specific implementation recommendations:

Initial Perceptions and Usability: participants described Motion Health VR as an innovative tool with the potential to transform rehabilitation, considering it essential, enjoyable, and valuable for promoting movement recovery, although recognizing its high cost. The intuitiveness of the game for older stroke patients generated mixed opinions, reflecting a range from perceiving its complexity to affirming that it provides sufficiently clear and accessible instructions. Game activities aligned with daily tasks were seen as advantageous for facilitating the integration of exercise into patients daily lives.

Motivation and Engagement: the ability of Motion Health VR to engage and motivate patients was attributed to several factors, including body movement control, perceived benefits relative to cost, and realistic environment representation. These elements are crucial for keeping patients committed to their rehabilitation in the long term, highlighting the importance of personalizing the game to reflect each patients individual and cultural realities.

Effectiveness of Game Mechanics and Feedback: the games ability to improve coordination and precision, especially in movements such as shoulder flexion and elbow extension, as well as in daily life activities, was acknowledged. The need for effective feedback was emphasized, suggesting improvements such as avatar imitation to optimize motor learning and prevent the adoption of incorrect movement patterns.

Integration into Clinical Practice and Implementation Challenges: the group recognized the value of integrating Motion Health VR into rehabilitation, noting its utility in recreating complex situations and its applicability in various areas of physiotherapy. However, challenges related to the personalization of the game according to individual patient needs and associated costs were highlighted, underscoring the need for strategies to overcome these barriers.

Comparison with Traditional Methods and Recommendations: when comparing Motion Health VR with traditional methods, the physiatrist doctor acknowledged its unique advantages, such as the ability to perform repetitive and engaging exercises, which can significantly improve mobility. However, they also emphasized the importance of not relying solely on VR technology, underscoring that it should complement, not replace, conventional therapies using kinesiological techniques and objects like stress balls or weights. These traditional modalities remain essential for developing strength and manual coordination in patients.

The focus group provided a variety of perspectives on the use of Motion Health VR for the rehabilitation of stroke patients. The feedback was grouped into four main categories: First Impression, Activity Intuitiveness, Disadvantages, and Recommendations. Physiotherapists described the system as a potentially useful and essential tool for rehabilitation, though some expressed concerns about its cost and accessibility. Opinions were divided on the intuitiveness of the games activities; some physiotherapists found the system interactive and fun, while others mentioned that the complexity of the activities could be a challenge for stroke patients. The main disadvantages identified were the need to adapt the system to each patients physical variables and the associated financial costs, as well as the technological barriers that some patients might face. Regarding recommendations, physiotherapists suggested using Motion Health VR under professional supervision, highlighting the importance of continuous monitoring and a carefully studied implementation. These categories and their respective opinions are summarized in the following affinity diagram (see Figure 5).

Physiotherapists supported the recommendation to use Motion Health VR under professional supervision and in appropriate circumstances, but also stressed the need to integrate these technological resources with proven and true methods of physical rehabilitation. During the focus group, they discussed how, although VR can increase motivation and provide a controlled and safe environment for movement practice, direct physical interaction and exercises with real resistance are irreplaceable for certain aspects of muscular and neurological recovery.

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Additionally, they expressed concerns about the practical and economic challenges posed by the implementation of VR, including initial costs and the necessary training for healthcare professionals [40]. This underscores the need for a balanced approach that values both new technologies and traditional techniques, ensuring comprehensive treatment that leverages the best of both worlds to meet the specific needs of each patient in their post-stroke rehabilitation process [41].

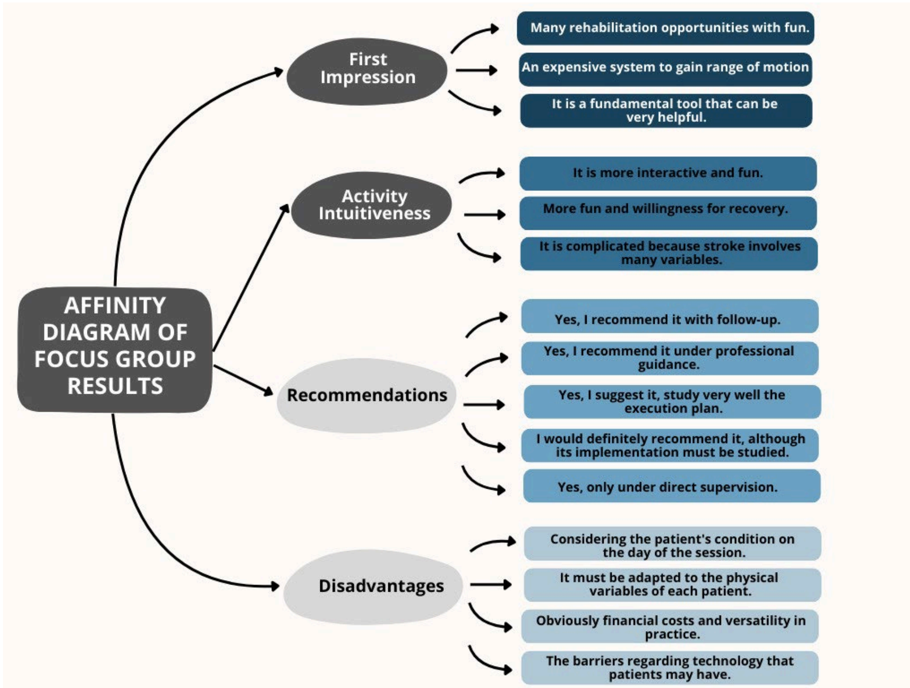

Figure 5: Affinity Diagram of Focus Group Perceptions on Motion Health VR.
Source: own elaboration.

4.3 Strategy 3: Feasibility and Cost-Effectiveness Analysis in the Colombian Context

Cost Evaluation: implementing Motion Health VR in the Colombian context involves significant initial costs. These costs include the acquisition of virtual reality (VR) devices, specialized software, and staff training. The average price of a VR device like the Meta Quest 2 is approximately $2.000.00 COP. The specialized software required for Motion Health VR can cost around $3.000.000 COP, and staff training to effectively use this technology can incur an additional cost of approximately $1.000.000 COP per physiotherapist. These Upfront expenses are significant, but in the long term, they are expected to result in significant savings due to reduced therapy durations and improved patient outcomes [42].

For example, implementation costs of VR exergames and custom-built rehabilitation games can be amortized over several years, with the expectation that the initial investment in VR technology will be recouped through reduced frequency and duration of traditional therapies. Additionally, the ability of these VR technologies to provide detailed data on patient progress allows for more effective treatment customization, leading to faster and more efficient results. This real-time monitoring and adaptive feedback can significantly enhance patient outcomes and overall satisfaction. Furthermore, the immersive and engaging nature of VR can increase patient motivation and adherence to rehabilitation programs, which are critical factors in achieving successful rehabilitation outcomes [43].

Financing Strategies: to facilitate the adoption of this technology in Colombia, various financing strategies can be explored. Colombian banks, such as Bancolombia and Davivienda, offer specific loans for medical equipment with preferential interest rates. These financial institutions could collaborate with rehabilitation centers to offer accessible financing packages that cover the acquisition and maintenance of VR equipment.

Additionally, the Colombian government, through the Ministry of Health and Social Protection, could provide grants or financing through programs like the Health Innovation Fund [44]. These funds could be allocated for the purchase of equipment and software, as well as staff training. Collaborations with technology companies and leasing programs could also be viable options to reduce initial costs. For example, companies like Google and Microsoft have shown interest in collaborating with health institutions to implement innovative technologies through leasing agreements or donations[45], [46].

Cost-Benefit Analysis: in rural areas of Colombia, where access to rehabilitation services is limited, renting a VR device with Motion Health VR for one or two months can be an effective solution. The rental cost of a VR headset can be approximately $200.000 COP per month. This cost is significantly lower compared to the expenses of transportation and accommodation that rural patients would incur traveling to cities for treatment. The ability to conduct therapy from home using Motion Health VR not only reduces these costs but also improves treatment adherence due to the convenience and accessibility of the home environment. For example, if a patient in a rural area of Colombia needs to travel to Bogotá for treatment, transportation and accommodation costs can range between $150.000 COP and $300.000 COP per trip. If the treatment requires weekly visits, the total cost can exceed $2.400.000 COP in two months. By renting a VR device for two months at $200.000 COP per month, the total cost would be $400.000 COP, representing significant savings and eliminating the need for frequent travel.

Comparison with Traditional Therapies: compared to traditional therapies that require regular visits to rehabilitation centers in cities, Motion Health VR offers the advantage of allowing patients to conduct their therapy from home. The cost of a package of 16 traditional therapy sessions (2 weekly for 8 weeks) at well-known rehabilitation centers in Colombia can range between $1.600.000 COP and $2.400.000 COP. By renting a VR device for two months at $200.000 COP per month, rural patients can complement their traditional therapies with VR sessions, avoiding additional transportation and accommodation costs and enhancing their rehabilitation without the need to travel [47].

Traditional therapies require the physical presence of a physiotherapist, which can limit the flexibility of treatment schedules. With Motion Health VR, patients can conduct their rehabilitation sessions at any time of the day, accommodating their personal schedules and needs. This not only improves treatment adherence but also allows physiotherapists to remotely supervise more patients, optimizing their time and resources.

Long-Term Economic Impact: the implementation of Motion Health VR can have a positive long-term economic impact, especially in rural areas. By improving access to rehabilitation, the economic burden on families who must bear transportation and accommodation costs is reduced. Additionally, by improving patients functional outcomes, the costs associated with long-term care and complications arising from incomplete recovery can be reduced. The ability to conduct therapy remotely also contributes to the sustainability of the healthcare system by reducing the pressure on rehabilitation centers in cities.

For example, a patient who achieves faster and more effective recovery with Motion Health VR may reduce their need for ongoing care and medications, resulting in significant savings for the healthcare system. Additionally, the ability to conduct therapy at home reduces the risk of nosocomial infections and other health problems associated with frequent visits to rehabilitation centers.

Proposals to Improve Accessibility: to improve the accessibility of Motion Health VR, it is essential to develop initiatives that reduce initial costs. The price of VR devices is decreasing, facilitating their acquisition by individuals and rehabilitation centers [48]. Specific financing programs for rehabilitation clinics, as well as the promotion of collaborations between the public and private sectors, can ensure broader and more effective adoption of the technology [49]. Additionally, providing specialized training and continuous technical support to physiotherapists is crucial to maximize the effectiveness of these technologies in the rehabilitation process [50],[51].

4.4 SWOT Analysis

The SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the implementation of Motion Health VR in the Colombian context reveals several key points: Among the strengths, custom-built VR exergames introduce an innovative technology that can significantly improve rehabilitation outcomes. Virtual reality allows the creation of controlled and safe training environments that can be adapted to the specific needs of each patient. This level of customization is difficult to achieve in traditional therapies and can accelerate the recovery process. Additionally, the use of VR can increase patient motivation and engagement with their therapy, making rehabilitation sessions more attractive and enjoyable. The ability to adjust the difficulty of the exercises according to the patient's needs offers a personalized experience, allowing for progressive rehabilitation. Remote accessibility is another great advantage, enabling patients in rural areas to receive treatment without the need to travel, saving time and money.

Opportunities include the possibility of securing financing through banks and government programs. The Colombian government, through public health initiatives and innovation funds, can offer grants and low-interest loans for the acquisition of VR technology, facilitating implementation in both public and private rehabilitation centers. As VR technology prices decrease, its adoption may become more accessible. Collaborations with technology companies and the public sector can facilitate adoption and reduce initial costs. The growing interest and acceptance of innovative technologies in the healthcare field also represents an opportunity to expand the use of custom-built VR exergames. Weaknesses include the successful implementation of VR exergames depending on adequate staff training, requiring an initial investment in training and ongoing professional development programs. The lack of familiarity with VR technology can be a barrier to its adoption by some healthcare professionals, leading to resistance to change and a steep learning curve. Initial costs and lack of access to financing can limit adoption, perpetuating inequality in access to advanced treatments. Dependence on technology and potential technical issues are another significant weakness. The efficacy of the treatment depends on the availability and functionality of VR technology, and technical problems can disrupt rehabilitation programs.

Threats include resistance to switching from traditional methods to new technologies. Traditional rehabilitation methods are well-established and widely accepted, and the introduction of new technologies may face skepticism and resistance from healthcare professionals. Potential technical and maintenance issues that could arise with the use of VR technology are an additional threat. Additionally, compliance with local regulations and standards can be complex, and the lack of clear regulations for the use of VR in rehabilitation can create uncertainty and hinder adoption (see Figure 6).

Strengths: the technological innovation of Motion Health VR can significantly improve rehabilitation outcomes by increasing patient motivation and engagement. The ability to customize the rehabilitation experience and provide remote accessibility are important advantages that can enhance the effectiveness and efficiency of therapies [52]. These findings align with other studies that have highlighted the importance of personalization and accessibility in the success of rehabilitation technologies [53].

Figure 6: SWOT Analysis of the Implementation of Motion Health VR in Post-Stroke Rehabilitation.
Source: own elaboration.

Opportunities: There are opportunities to secure financing through banks and government programs, as well as to establish public-private partnerships that reduce initial costs. The growing interest and acceptance of innovative technologies in the healthcare sector also represent an opportunity to expand the use of Motion Health VR. Comparatively, other studies have indicated that financing policies and strategic partnerships are crucial for the adoption of new technologies in the healthcare sector [54],[55].

Weaknesses: High initial costs and the need for specialized training are significant barriers. The lack of familiarity with VR technology among some healthcare professionals can create resistance to change and hinder adoption. Dependence on technology and potential technical issues are also major challenges. These weaknesses reflect similar concerns found in other studies, where education and continuous training are essential for the successful integration of new technologies [55].

Threats: Resistance to switching from traditional methods to new technologies is a potential threat. Technical and maintenance issues can disrupt treatments and increase operational costs. Additionally, compliance with local regulations and standards can be complex and hinder the adoption of VR in rehabilitation. These threats are consistent with previous studies that have emphasized the importance of regulations and technical infrastructure in the implementation of health technologies [56].

4.5 Discussion

4.5.1 Strategy 1: Survey

The survey conducted during the ISPRM 2023 conference demonstrated substantial acceptance of VR technology among healthcare professionals for post-stroke rehabilitation, with 91.8 % of respondents recognizing the advantages of VR exergames like Motion Health VR. This highlights the potential for integrating these technologies into traditional rehabilitation protocols. However, significant barriers, including high costs (cited by 72.6 % of respondents) and limited accessibility (63.9 %), were identified. These findings are consistent with existing literature that emphasizes economic constraints and technological familiarity as critical challenges for implementation [7]. While acceptance among professionals is a strength, addressing these barriers requires institutional support, such as public-private partnerships to subsidize costs, and comprehensive training programs to enhance familiarity with the technology. Incremental deployment through pilot programs may further refine implementation strategies, providing a foundation for broader adoption [18].

4.5.2 Strategy 2: Focus Group

The focus group provided detailed qualitative insights into the advantages and limitations of Motion Health VR. Physiotherapists valued the tool's ability to enhance patient motivation and facilitate therapeutic movements, such as shoulder flexion and elbow extension. These findings align with previous studies that underline the motivational potential of VR in improving rehabilitation outcomes [57]. However, challenges such as the complexity of use for older patients and the need for effective real-time feedback were evident. These limitations suggest the importance of refining the system's usability, particularly through interface simplifications and the incorporation of biofeedback mechanisms to optimize therapeutic engagement. Furthermore, leveraging supervised sessions in early adoption phases could address usability challenges while reinforcing clinician confidence. This approach supports a balanced integration of VR technologies with traditional kinesiotherapy techniques, ensuring comprehensive therapeutic outcomes [58], [59].

4.5.3 Strategy 3: Feasibility Cost-Effectiveness Analysis

The feasibility and cost-effectiveness analysis underscored that, despite significant upfront costs associated with equipment, software, and training, Motion Health VR offers long-term economic benefits through reduced therapy durations and improved patient outcomes. These findings highlight the potential for VR technologies to complement traditional rehabilitation in resource-limited contexts like rural Colombia. Nevertheless, the initial financial burden poses a substantial barrier to accessibility. Practical solutions, such as shared ownership models and targeted government subsidies, could help offset these costs. Additionally, the integration of VR technologies with telemedicine systems may enhance accessibility by reducing the need for patient travel while maintaining high standards of care. These strategies are essential for ensuring the scalability and sustainability of Motion Health VR in diverse healthcare settings [60]-[64].

SWOT Analysis: The SWOT analysis of Motion Health VR highlights the interplay between its potential and the barriers to its implementation. Strengths such as customization, patient motivation, and remote accessibility are juxtaposed with challenges like high costs, technical dependence, and resistance among healthcare professionals to adopting new technologies. To address these barriers, targeted strategies such as awareness campaigns, workshops, and collaborative initiatives with technology providers can be implemented. Furthermore, developing regulatory frameworks that provide clear guidelines for the clinical use of VR will ensure its safe and effective integration. These measures are critical for leveraging the strengths of Motion Health VR while mitigating its weaknesses, enabling broader adoption in Colombia is healthcare system.

By systematically addressing the identified limitations and implementing evidence-based strategies, this discussion provides a pathway to transition Motion Health VR from a novel technology to a practical tool for post-stroke rehabilitation. Future research should focus on longitudinal validation of outcomes, scalability in diverse populations, and the economic feasibility of sustained implementation. These efforts will ensure that the potential benefits of VR-based interventions are fully realized while overcoming the barriers to their widespread adoption.

4.6 Limitations

One of the main limitations of this study was the context of the massive event in which it took place, the ISPRM 2023 Conference. The nature of the event meant that attendees moved freely and engaged in activities that captured their interests, posing a challenge for systematic data collection. Although efforts were made to involve a variety of medical specialists, the events dynamics made constant and in-depth interaction with patients difficult.

The recruitment of specialists was influenced by the perception of technology as a novelty and by specialists personal conviction that this technology could be incorporated into their daily practice. Despite significant efforts to recruit patients, convincing specialists to participate was not straightforward. Many expressed interest, but converting this interest into effective participation in the study was complex due to the demands of their professional roles and possibly a lack of familiarity or skepticism towards new technologies.

These barriers underscore the need to adapt research strategies to the conditions of the environment and the characteristics of the target audience. For future studies, it would be beneficial to consider alternative methods that allow for more flexible data collection adapted to massive and dynamic environments, as well as more effective engagement strategies that align specialists interests with the study objectives.

5. CONCLUSIONS

This study has demonstrated the significant potential of virtual reality (VR) technology through applications such as Motion Health VR to enhance rehabilitation strategies for post-stroke patients. The acceptance by physiotherapists and other healthcare professionals indicates a favorable disposition towards adopting this innovative technology, perceived as effective in increasing patient motivation and engagement. Additionally, the feasibility and cost-effectiveness analysis in Colombia reveals that although initial costs are considerable, they can be offset in the long term by savings resulting from reduced therapy durations and improved patient outcomes. These findings emphasize the need for financing strategies, such as government grants and public-private collaborations, to overcome economic barriers and ensure equitable access, particularly in underserved rural areas.

The focus group results underscore the advantages of Motion Health VR in motivating patients and facilitating specific therapeutic movements, while also highlighting challenges such as high initial costs and complexity of use for certain patients, especially older adults. These challenges underline the importance of improving usability through simplified interfaces and incorporating features like real-time feedback to optimize patient engagement. The SWOT analysis further reveals critical strengths, such as customization and remote accessibility, alongside opportunities for securing funding and fostering public-private partnerships. At the same time, it identifies limitations, including resistance to changing traditional rehabilitation methods and potential technical difficulties.

Reinforcing these findings, the study provides actionable insights to inform clinical practice and public policy. Implementing Motion Health VR in clinical settings will require not only technological adaptation but also systemic changes, such as integrating VR into rehabilitation protocols, developing targeted training programs for healthcare professionals, and promoting awareness campaigns to reduce resistance to innovation. Policymakers can play a key role by prioritizing investments in VR technology, establishing regulatory frameworks to support its adoption, and incentivizing research to further validate its long-term benefits.

In summary, this study confirms the value of VR-based interventions and suggests that, with adequate support and strategic implementation, Motion Health VR can become a transformative tool for physical rehabilitation, improving the quality of life for post-stroke patients in Colombia and contributing to broader health equity in the region.

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CONFLICTS OF INTEREST

The authors declare no financial, personal, or professional conflicts of interest related to this manuscript. The study was conducted independently, without external influences that could compromise the objectivity of the results.

AUTHOR CONTRIBUTIONS

Julián Felipe Villada Castillo: Conceptualization, Methodology design, Drafting.
José Fernando López: Data Analysis, Methodology, Results. Additionally, Editing.
John Edison Muñoz: Design and technical development of the exergame Motion Health VR, including its game mechanics. Also provided support in integrating graphical content and conducting the technical review of the manuscript.
Oscar Henao Gallo: Literature review, Drafting.

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