ORIGINAL ARTICLE CONTENTS

Virtual reality as a supplement to traditional rehabilitation after strokes: a preliminary study on therapy effectiveness

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ABSTRACT

Aim: To assess whether virtual reality (VR) rehabilitation would be an effective adjunct to standard therapy in improving outcomes in stroke patients. The secondary objective was to investigate whether VR therapy would improve quality of life and reduce pain levels compared to traditional rehabilitation.

Materials and methods: The study was conducted with stroke patients undergoing rehabilitation at the Department of Rehabilitation and Orthopedics. The collected data were randomly divided into two groups: an experimental group that received VR-assisted rehabilitation and a control group that received only conventional rehabilitation for two weeks, six days a week. The outcome measures in determining the effectiveness of rehabilitation were the EQ-5D and VAS scales.

Results: There were no significant differences between the experimental and control groups in terms of quality of life and pain scores. However, both groups showed improvement over time, indicating overall effectiveness of the rehabilitation. The experimental group showed significant improvement in pain reduction, suggesting a beneficial effect of VR therapy. The small sample size limited the detection of significant differences between groups.

Conclusions: VR-assisted rehabilitation may help reduce pain in stroke patients, but its impact on overall quality of life remains uncertain. Further studies with larger groups and longer follow-up are needed to fully understand the potential of VR to improve conventional rehabilitation practices.

KEY WORDS: rehabilitation, neurorehabilitation, virtual reality, functional recovery

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INTRODUCTION

Rehabilitation is a key component of healthcare, and the technological advancements associated with it enable the implementation of innovative strategies to support this process [1]. Specifically, physiotherapy is widely used as part of comprehensive therapy or as a standalone intervention in disease management. Rehabilitation is routinely implemented after surgical procedures, facilitating the restoration of damaged organ function and maintaining therapeutic outcomes. In recent decades, emerging technologies have evolved from the simplest forms of biofeedback to advanced virtual reality systems [2]. Patients admitted to rehabilitation units predominantly face neurological conditions, such as stroke.

Stroke is the 2nd leading cause of death and the third leading cause of adult disability worldwide with most survivors reporting dysfunctions of motor, sensation, deglutition or speech [3-5]. Around 80% of stroke survivors experience difficulty walking. Even after rehabilitation, about a quarter still have lasting gait issues that require assistance with daily activities. Additionally, nearly half of stroke patients experience falls after being discharged [3]. It also has a major emotional and socioeconomic impact [6]. Therefore, effective rehabilitation after a stroke is essential for regaining functional independence and restoring cognitive function [3, 6].

Treatments for all patients are prescribed by the attending physician with the active participation of the physiotherapist responsible for the patient. The rehabilitation methods employed are individually tailored to the patients' health status and psychosomatic capabilities. These methods include, among others, the Proprioceptive Neuromuscular Facilitation (PNF) technique, balance exercises, isometric exercises, active-passive exercises, and active breathing exercises. The therapy also utilizes robotic devices and equipment, active verticalization, training in locomotor activities and gait training with orthopedic aids. Patients participate in general mobility exercises, both individually and in groups, as well as music therapy and autogenic training. Additionally, motor coordination

Table 1. Rehabilitation summary

Control group	Examinated group
-Proprioceptive Neuromuscular Facilitation 20min -Individual work with the patient 20 min -Balance, coordination, isometric exercises 20 min -Manual dexterity exercises, self-care exercises 20 min -Passive active exercises, equipment exercises 20 min -Active verticalization, locomotion with devices, independent locomotion training 20min -Robotic devices training 45 min -Breathing exercises 15 min -Autogenic training, music therapy 30 min	-Proprioceptive Neuromuscular Facilitation 20min -Individual work with the patient 20 min -Balance, coordination, isometric exercises 20 min -Manual dexterity exercises, self-care exercises 20 min -Passive active exercises, equipment exercises 20 min -Active verticalization, locomotion with devices, independent locomotion training 20min -Robotic devices training 45 min -Breathing exercises 15 min -Autogenic training, music therapy 30 min VR reality exercises: -Tailored skills training -Relaxation training 60 min

exercises, self-care exercises, active aquatic exercises and manual dexterity exercises are implemented.

One emerging technology with the potential to enhance and further transform the field of orthopedics is virtual reality (VR). VR has been extensively researched and applied in various medical fields, including clinical applications such as psychiatric therapy, pain management, rehabilitation and traumatic brain injury [7]. The effectiveness of VR-based rehabilitation has been validated in Parkinson's disease, stroke and cerebral palsy. In orthopedic rehabilitation, the benefits of VR-based interventions have been investigated in patients with osteoarthritis, sacroiliac pain and anterior cruciate ligament injury [8].

AIM

The present study was conducted to determine whether virtual reality (VR) assisted rehabilitation can complement conventional therapy and significantly impact treatment outcomes. The study compared the effects of therapy in an experimental/study group (traditional rehabilitation + VR) and a control group (traditional rehabilitation only).

The objectives of the study were to examine whether:

1) Rehabilitation incorporating the use of VR positively influences the quality of life of patients undergoing therapy.
2) VR therapy affects the level of pain experienced by patients.

MATERIALS AND METHODS

PARTICIPANTS

The study sample consisted of a group of sixteen adults, women and men (with a mean age of 61.375 years), who were qualified for rehabilitation at the Clinical Department of Rehabilitation and Orthopedics following a stroke. The study was conducted from April 2023 to May 2024.

Exclusion criteria for participation in the study included: negative psychological assessment, epilepsy, complete impairment of upper limb movement, dizziness and persistent sensation of instability in the sitting position.

Participants were randomly assigned to either the experimental group with VR rehabilitation (n=7, 1 woman and 6 men) or the control group (n=9, 2 women and 7 men).

INTERVENTIONS

Rehabilitation for patients in the control group was carried out according to the protocol used at the Clinic, 6 days a week, divided into a morning and an afternoon session. In the study group, the interventions were further extended with a session using VR goggles also 6 days a week (Table 1, Fig. 1). The VR exercises included tailored skills training and relaxation exercises. The follow-up period in both groups was two weeks.

MAIN OUTCOME MEASURES

Standard clinical assessment tools were used to evaluate the results of rehabilitation with VR technology both before and after the rehabilitation process. The VAS scale (the Visual Analogue Scale) allows patients to subjectively assess pain intensity. The EQ-5D-L (European Quality of Life 5 Dimensions 5 Level Version) questionnaire assesses quality of life across various aspects, such as mobility, daily activities and psychological well-being. With these tools, a comprehensive picture of the effectiveness of the therapy and its impact on the patient's life was obtained.

Fig. 1. Patient during the VR therapeutic session.

Statistical analyses were performed using the NCSS 20 statistical package. The results of the scales were analyzed by group and time point and compared using two-way analysis of variance and post-hoc Tukey's test. A p-value of <0.05 was considered statistically significant and a p-value of <0.01 was considered highly significant.

RESULTS

There was no significant (p>0.05) difference in EQ-5D-L scale scores between the experimental and control groups. A significant difference (p<0.05) was found between the time points, with scores after the rehabilitation period being lower than those before the therapy. The effect size, as measured by the partial eta squared coefficient, was approximately 37% and the power of the test was about 77%. Post-hoc analyses did not reveal such differences within each group separately, which is due to the small sample size. No significant (p>0.05) interaction was observed between the group and time factors (Table 2; Fig. 2). These results suggest that rehabilitation had a significant impact on improving patients' quality of life, regardless of whether they belonged to the experimental or control group. The lack of difference between the groups indicates that the additional rehabilitation used in the experimental group provided no extra benefit compared to standard therapy.

There was no significant (p>0.05) difference in VAS scale scores between the experimental and control groups. A highly significant difference (p<0.01) was found between the time points, i.e. after rehabilitation, the scores were significantly lower than before. The effect size, as measured by the partial eta squared coefficient was about 52% and the power of the test was about 95%. Post-hoc analyses did not reveal such differences in the control group, which is due to the small sample size, but in the experimental group the difference between time points was high enough to become significant when considered only within this group. No significant (p>0.05) interaction was observed between the group and time factors (Table 3; Fig. 3). The results indicate that rehabilitation significantly reduced patients' perceived pain, regardless of whether they belonged to the experimental or control group. However, in the post-hoc analysis the improvement was statistically significant only in the experimental group, suggesting that the additional rehabilitation with VR goggles used in the experimental group may have had a stronger pain-reducing effect in the rehabilitation process.

There was no interaction between the group and survey responses before and after rehabilitation, indicating that the changes over time affected all participants in general, not just one group. There were no statistically significant differences between the experimental and control groups on any of the used scales (EQ-5D, VAS) suggesting that the VR rehabilitation analyzed had no clear effect on the assessed parameters. The small sample size may have limited the ability to detect differences in the control group.

DISCUSSION

Available studies show that VR has a positive impact on the rehabilitation process of post-stroke patients by

Table 2. Results of the scale – EQ-5DL

Term	Group	Arithmetic mean	Standard deviation	Standard error of the mean	-95% CI for the group average	+95% CI for the group average
Before	Experimental	11.00 a	4.00	1.51	7.30	14.70
	Control	10.22 a	4.02	1.34	7.13	13.32
After	Experimental	9.43 a	3.69	1.39	6.02	12.84
	Control	8.78 a	3.03	1.01	6.45	11.11
ANOVA						
Group	$F=0.16; p=0.6949; \eta^2=0.0113; 1-\beta=0.0661$					
Term	$F=8.36; p=0.0118; \eta^2=0.3740; 1-\beta=0.7672$					
Interaction	$F=0.01; p=0.9048; \eta^2=0.0011; 1-\beta=0.0515$					

CI- confidence interval; a, b, ab – labels indicating the results of the post-hoc test; F- F-test; p – p-value; η2- effect size; 1-β- test power

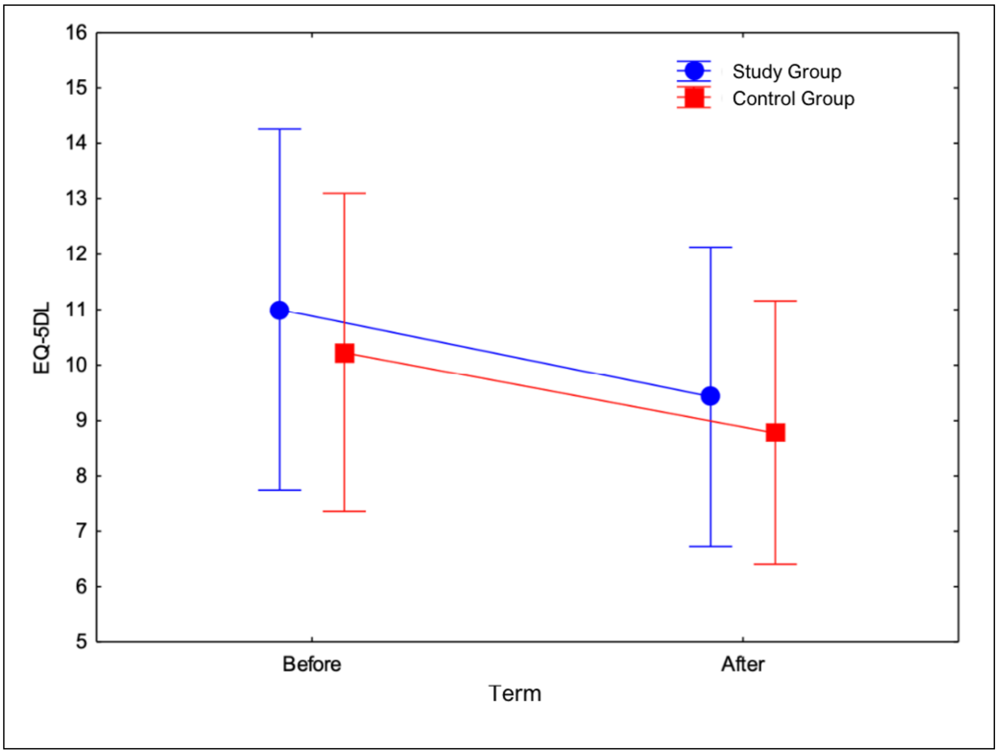

Fig. 2. Results of the scale – EQ-5DL.

significantly improving their mental health and relieving anxiety disorders [9, 10]. In addition, it has been shown that the use of VR can lead to improvements in patients with cognitive impairment and improved motor abilities leading to shorter hospitalization [11, 12]. The primary aim of the present study was to determine the effectiveness of rehabilitation enhanced by the use of VR goggles as an addition to standard therapy. Analysis of the results helps answer three crucial research questions: (1) whether rehabilitation with the use of VR technology improves patients' quality of life, and (2) does it reduce perceived pain.

The EQ-5D and VAS results showed a significant reduction in values after the rehabilitation period, which may indicate an improvement in participants' condition or quality of life during rehabilitation and a potential reduction of the influence of external factors such as fatigue. Longer follow-up may be needed to determine whether this trend is sustainable. Randomized controlled trials performed on 43 post-stroke patients indicate a reduction in values on the EQ-5D-5L scales after a period of rehabilitation using virtual reality [13].

The eta-square values suggest that for the EQ-5D the effect of time is moderate (37%), but post-hoc analysis did not show clear differences between groups, which may be due to the limited study group, which is an important limitation of the performed experiment.

Table 3. Results of the scale – VAS

Term	Group	Arithmetic mean	Standard deviation	Standard error of the mean	-95% CI for the group average	+95% CI for the group average
Before	Experimental	4.43 b	1.62	0.61	2.93	5.93
	Control	4.89 ab	1.36	0.45	3.84	5.94
After	Experimental	3.00 a	1.91	0.72	1.23	4.77
	Control	3.89 ab	2.03	0.68	2.33	5.45
ANOVA						
Group	F=0.67; p=0.4260; η^2=0,0458; 1-β=0.1192					
Term	F=14.97; p=0.0017; η^2=0.5168; 1-β=0.9487					
Interaction	F=0,47; p=0,5058; η^2=0,0322; 1-β=0,0976					

CI- confidence interval; a, b, ab – labels indicating the results of the post-hoc test; F- F-test; p- p-value; η^2- effect size; 1-β- test power

For VAS, the effect of time is large (52%) and has high statistical strength (95%), which indicates significant changes in pain reduction for patients in the experimental group, which cannot be found in the control group. The effectiveness of virtual reality in reducing different types of pain is also confirmed by KP Wong in his systematic review [14].

A major limitation is the small group size, which makes it challenging to detect significant differences in post-hoc analyses. This suggests the need to conduct the study on a larger group, which allows for more reliable results and to consider other methods of data analysis or additional measures to evaluate the impact of virtual reality on patients' conditions. Limitations of the equipment may be, in the case of balance assessment, the delay creating a sensory conflict that can lead to falls. Also important is the inability to replicate a perfectly realistic environment. VR-based rehabilitation equipment also presents technological difficulties to set up or required staff training [15].

There are many areas for future research. The directions for future studies include a better understanding of VR's mechanisms of action, personalizing therapy, and expanding its applicability to different types of pain. In contrast to many pain medications, which interfere with the C-fiber pathway, VR affects pain perception through attention, concentration and emotional changes which highlights the importance of research into the neural foundations of this method. The difference in efficacy between age groups also remains an important challenge, because VR therapy is better at alleviating pain intensity among adolescents than adults, suggesting the need to adapt the intervention to the specific characteristics of users. Moreover, VR has shown promising results in relieving acute pain, especially postoperative and procedural pain, but its effect on chronic pain remains inconclusive. At the same time, the methodological quality of studies should be improved, as most of the emerging evidence involves only specific populations, limiting the wider use of VR in pain treatment [16].

High-quality, controlled clinical trials are therefore necessary to determine the optimal protocols for using VR in patient rehabilitation. Despite inconclusive results and a lack of statistical significance, the studies show correlations indicating a possible positive impact of using virtual reality in addition to standard rehabilitation procedures. Such results are a good direction for the development of further research on the impact of virtual reality on processes that improve patient functional capacity.

Despite the lack of statistically significant differences based on the VAS scale, a noticeable reduction in pain can be observed among patients who were rehabilitated with the use of VR goggles. Further studies on a larger group of patients are needed to conclude unequivocally that expanding traditional rehabilitation with VR-based rehabilitation leads to significant improvements in treatment outcomes. The clinical implications of using VR in rehabilitation primarily include the possibility of increasing patient involvement in the therapeutic process, which can positively impact the effectiveness of this form of activation. Virtual reality can be a valuable supplement to standard therapy, especially in reducing pain and increasing patients' comfort.

CONCLUSIONS

Due to the limitations of the study, including the small study group, it is recommended that further studies should be conducted on a larger group of patients and

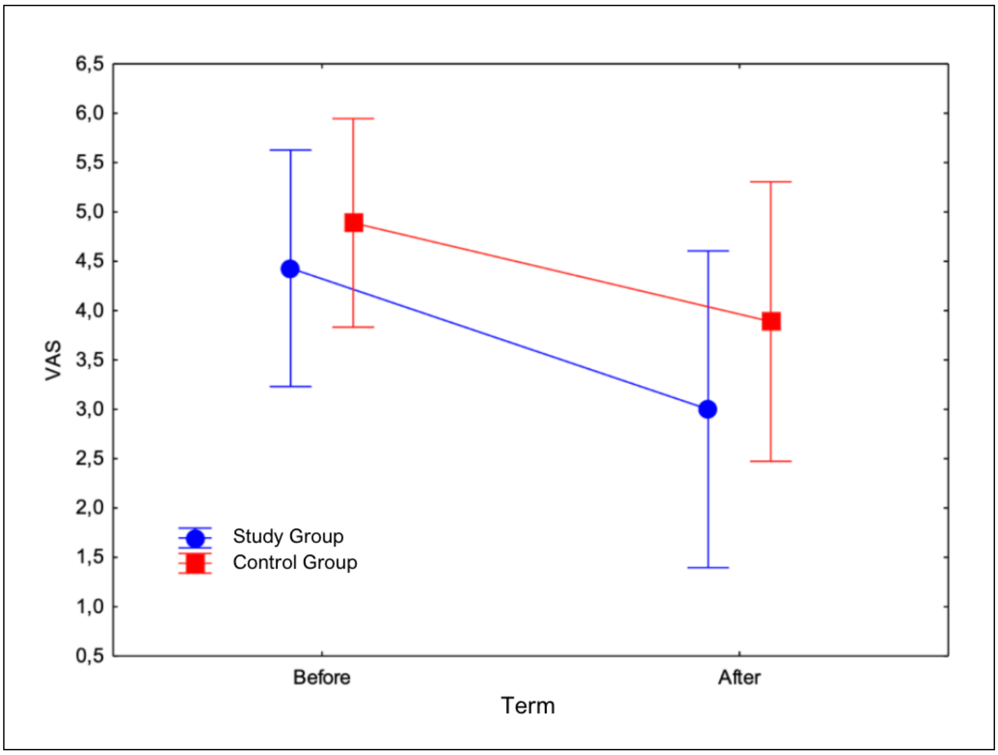

Fig. 3. Results of the scale – VAS.

that the effects of therapy should be monitored for a longer period of time to determine the sustainability of the achieved changes and to better comprehend the mechanisms of VR in the context of the rehabilitation. Consideration should also be given to optimizing interventions, including the personalization of VR therapy depending on the age of patients, the type of disability and the stage of the rehabilitation process. This study is an important starting point for further analysis of the use of VR technology in medical rehabilitation. The observed potential of this method indicates the need for further exploration and the achieved results can provide a foundation for designing future studies and optimizing the use of VR in the therapy.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest.

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