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# Use of virtual reality eyeglasses as an additional method in rehabilitation after upper limb injury

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*Over the past two decades, there has been a significant increase in the use of immersive technologies in rehabilitation. VR technologies allow for the simulation of motor tasks in a safe gaming digital environment, which contributes to better integration of the patient into the rehabilitation process, activates the neuromuscular system and reduces psychoemotional stress during the restoration of motor functions. While traditional methods involving simple, repetitive movements can be exhausting for patients and make them less motivated to continue treatment. Objective. Examined the effectiveness of using VR technology as an auxiliary method of rehabilitation in patients with traumatic injuries of the upper limbs after a blast injury. Materials. The effectiveness of using VR technology as an auxiliary rehabilitation method in patients with traumatic injuries of the upper extremities after a blast injury was analyzed. Results. The study included a case series of 4 military personnel with traumatic injuries of the upper limbs resulting from a blast injury. The rehabilitation program included standard physical therapy and physiotherapy methods in combination with training in a virtual environment using virtual reality glasses with the VR Vitalis program. Patients performed tasks aimed at improving coordination, strength and amplitude of movements in the shoulder, elbow and radiocarpal joints, considering the need for movement restoration. The dynamics of the range of motion was assessed using goniometry, muscle strength using dynamometry, and the level of motivation for classes was assessed using a survey. Conclusion. It was found that the use of VR technologies as an additional method to traditional rehabilitation contributed to a noticeable improvement in the indicators of functional recovery of upper limb movements. Positive dynamics were recorded not only in physical indicators, but also in the psycho-emotional state. All participants reported increased motivation and better involvement in the treatment process.*

*Протягом останніх років спостерігається значне зростання використання імерсивних технологій в реабілітації. VR-технології дозволяють моделювати рухові завдання в безпечному ігровому цифровому середовищі, що сприяє кращому інтегруванню пацієнта в процес реабілітації, активують нервово-м'язову систему та знижують психоемоційне навантаження під час відновлення рухових функцій, тоді як традиційні методи, які включають прості, повторювані рухи, можуть бути виснажливими для хворих і зменшувати мотивацію до лікування. Мета. Оцінити ефективність використання VR-технології як допоміжного методу реабілітації у пацієнтів із травматичними ушкодженнями верхніх кінцівок після вибухової травми. Матеріали. Проаналізовано ефективність використання VR-технології як допоміжного методу реабілітації в пацієнтів із травматичними ушкодженнями верхніх кінцівок після вибухової травми. Результати. У дослідження включено історії хвороб 4 військовослужбовців із травматичними ушкодженнями верхніх кінцівок. Реабілітаційна програма складалася зі стандартних методів фізичної терапії в поєднанні з тренуванням у віртуальному середовищі з використанням окулярів віртуальної реальності з програмою VR Vitalis. Пацієнти виконували завдання, спрямовані на покращення координації, сили й амплітуди рухів у плечовому, ліктьовому та променево-зап'ястковому суглобах. Аналіз динаміки обсягу рухів здійснювали за допомогою гоніометрії, сили м'язів — динамометрії та рівень мотивації до занять методом опитування. Висновок. Виявлено, що застосування VR-технологій як додаткового інструмента до традиційної реабілітації сприяло помітному покращенню показників функціонального відновлення рухів верхньої кінцівки. Зафіксовано позитивну динаміку не лише у фізичних показниках, а й у психоемоційному стані. Усі учасники повідомляли про зростання мотивації та кращу залученість у процес лікування. Ключові слова. Віртуальна реальність, ураження верхніх кінцівок, вибухова травма, реабілітація.*

**Keywords.** Virtual reality, upper limb injury, blast injury, rehabilitation

## Introduction

Over the past two decades, there has been a significant increase in the use of immersive technologies in rehabilitation. These technologies include Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), collectively referred to as Extended Reality (XR) [1]. Among these, VR technologies are the most popular today, as they allow the patient to be immersed in a fully controlled three-dimensional environment, while AR technologies overlay VR elements onto the real-world environment in the form of real-time video displayed on an electronic device screen [2]. Therefore, AR is useful for training doctors on a virtual patient, detailed planning of medical interventions, and even enhancing intraoperative navigation [3]. VR technologies allow the simulation of movement tasks in a safe, game-like digital environment, promoting better integration of the patient into the rehabilitation process [4], activating the neuromuscular system, and reducing emotional stress during the recovery of motor functions [5]. In contrast, traditional methods that involve simple repetitive movements may be exhausting for patients and reduce motivation to continue treatment [6].

In the context of an increase in explosive and mine-related trauma (EMT) among both military personnel and civilians [7], the issue of effective rehabilitation after injuries to the upper limbs becomes especially important. Chronic pain, peripheral nerve damage, and functional limitations are the primary barriers to optimal recovery for patients following traumatic injuries to this area [8]. Traditional physical exercises require significant time and focus from the patient, which can reduce their motivation to engage in rehabilitation. The use of VR technology as an adjunctive method makes the rehabilitation process more interactive and psychologically comfortable, enhancing the effectiveness of restoring motor function [9].

*Purpose:* To assess the effectiveness of using VR technology as an adjunctive method in the rehabilitation of patients with traumatic injuries to the upper limbs following blast trauma.

## Materials and methods

The study included 4 cases of rehabilitation treatment for military personnel with traumatic injuries to the upper limbs resulting from blast trauma. The rehabilitation program combined standard physical therapy methods with training in a virtual environment using VR headsets (VR glasses) and the VR Vitalis software. Patients performed tasks aimed at improving coordination, strength, and range of motion in the shoulder, elbow, and wrist joints. The dynamics of range of motion were analyzed using goniometry, muscle strength was measured using a dynamometer, and motivation levels were assessed through surveys.

The study was conducted in accordance with bioethical principles, legislative requirements, and the Helsinki Declaration, the Constitution of Ukraine, and the fundamentals of Ukrainian legislation. It was carried out as part of the standard rehabilitation process with written informed consent obtained from the patients and approved by the bioethics committee of the State Institution Professor M. I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine, Kharkiv (Protocol No. 259 dated 29.01.2026).

## Results

After two weeks of training with VR headsets, all patients showed improvement in range of motion and muscle strength. Virtual tasks designed to simulate daily activities (e.g., grasping objects, rotational movements, etc.) stimulated the activation of fine motor skills, coordination, and proprioception. Over time, there was noticeable restoration of movement control and reduction in rigidity of the affected segments.

*Case study No. 1*

A 28-year-old patient D. Diagnosis: consequences of blast injury (May 2022), post-traumatic osteoarthritis of the left shoulder joint. Severe pain syndrome. Deformation of the II-III fingers of the left hand. Impaired hand function. Median nerve neuropathy on the left (Table 1). Moderate but stable improvement in the range of motion of the left shoulder joint was observed. Flexion increased by 12°, extension by 3°, abduction by 2°, indicating a positive impact of therapy on the capsular-ligamentous and muscle apparatus of the shoulder girdle. More significant changes were recorded in strength parameters (%): flexor muscle strength increased by 32.9 %, extensor strength by 53.6 %, adductor strength by 21.3 %, and abductor strength by 24.5 %. A similar positive dynamics was noted in the radiocarpal joint, where the maximum increase in the range of motion was observed during dorsal flexion (+18°).

*Case study No. 2*

A 36-year-old patient A. Diagnosis: consequences of a gunshot fragment injury (03.10.2024): multiple blind fragment injuries of both upper and lower limbs with foreign bodies (metal fragments); consolidated fracture of the II metacarpal bone of the right hand with mixed contracture of the 2-5 metacarpoph-

alangeal joints of the right radiocarpal joint with moderate dysfunction; post-traumatic neuropathy of the right radial and ulnar nerves, left ulnar nerve with moderate sensorimotor disorders; post-operative hardened skin scars with minor functional impairment (Table 2). Due to severe neurological and structural limitations, improvement in the range of motion was minimal. However, dynamometric parameters showed functionally significant improvement. The greatest strength increase was recorded in the finger flexors (+45.5%) and the muscles responsible for wrist flexion (+25.0%).

*Case study No. 3*

A 33-year-old patient Y. Diagnosis: consequences of a gunshot fragment injury (18.03.2024): consolidated fractures of both bones of the left forearm, fixed with metal constructs in the middle third. Combined contracture of the left elbow and radiocarpal joints. Post-traumatic ulnar nerve neuropathy (Table 3). The patient showed improvement in both range of motion and muscle strength. In the elbow joint, there was a reduction in extension deficit by 6° and an increase in flexion by 5°. In the radiocarpal joint, significant improvement was observed in palmar flexion (+13°). Dynamometry revealed a significant increase in strength: elbow flexors increased by 70.6 %, extensors by 46.3 %. The most notable result was the doubling of finger flexor strength (+100 %), which has high clinical significance for the recovery of self-care functions.

*Case study No. 4*

A 30-year-old patient B. Diagnosis: consequences of a gunshot fragment injury (28.03.2025) to the left hand: weakly consolidated gunshot fracture of the II metacarpal bone, pseudoarthrosis and gunshot bone defect of the III metacarpal bone with displacement. Post-operative stage after left hand surgical treatment: revision of the fracture zone of the III metacarpal bone, installation of a rod (19.08.2025), resection of the upper third of the right fibula, autoplasty of the fibula bone defect in the III metacarpal bone, removal of the rod, and MOS of the III metacarpal bone with a plate and screws (02.09.2025). Combined contracture of the left hand.

*Table 1*

**Functional evaluation of the joints in the left upper limb of patient D.**

| Indicator | Initial value | Final value |
|---|---|---|
| Goniometry<br>– Shoulder joint;<br>– Radiocarpal joint | Extension/Flexion: 47°/0°/135°,<br>Abduction/Adduction: 123°/0°/44°<br>Dorsal/Palmar flexion: 60°/0°/73°,<br>Elbow/Radial flexion: 23°/0°/52° | Extension/Flexion: 50°/0°/147°,<br>Abduction/Adduction: 125°/0°/44°<br>Dorsal/Palmar flexion: 78°/0°/83°,<br>Elbow/Radial flexion: 25°/0°/54° |
| Dynamometry, kg<br>(Shoulder joint): | Flexors —14.0; Extensors — 8.4;<br>Adductors — 10.8; Abductors — 11.0 | Flexors — 18.6; Extensors — 12.9;<br>Adductors — 13.1; Abductors — 13.7 |

*Table 2*

**Functional evaluation of the right radiocarpal joint of patient A.**

| Indicator | Initial value | Final value |
|---|---|---|
| Goniometry<br>(right radiocarpal joint) | Dorsal/Palmar flexion: 0°/23°/65°;<br>Ulnar/Radial flexion: 0°/10°/18° | Dorsal/Palmar flexion: 0°/17°/65°;<br>Ulnar/Radial flexion: 2°/0°/17° |
| Dynamometry, kg<br>(right radiocarpal joint) | Dorsal flexion: 0.4; Palmar flexion: 8.3;<br>Ulnar flexion: 6.6; Radial flexion: 3.2;<br>Finger flexors: 11.0 | Dorsal flexion: 1.0; Palmar flexion: 8.6;<br>Ulnar flexion: 6.6; Radial flexion: 4.0;<br>Finger flexors: 16.0 |

*Table 3*

**Functional assessment of left upper limb joints of patient E.**

| Indicator | Initial value | Final value |
|---|---|---|
| Goniometry<br>– Elbow joint:<br>– Radiocarpal joint: | Flexion/Extension: 0°/21°/138°<br>Dorsal/Palmar flexion 36°/0°/37°;<br>Ulnar/Radial flexion: 21°/0°/21° | Flexion/Extension: 0°/15°/143°<br>Dorsal/Palmar flexion: 45°/0°/50°<br>Ulnar/Radial flexion: 22°/0°/25° |
| Dynamometry (kg)<br>– Radiocarpal joint;<br><br>– Elbow joint | Dorsal flexion: 1.9; Palmar flexion: 2.7<br>Ulnar flexion: 2.2; Radial flexion: 2.7<br>Finger flexors: 5.0<br>Flexors: 3.4; Extensors: 4.1 | Dorsal flexion: 2.4; Palmar flexion: 4.3<br>Ulnar flexion: 5.6; Radial flexion: 3.2<br>Finger flexors: 10.0; Elbow joint:<br>Flexors: 5.8; Extensors: 6.0 |

Temporary loss of function of the left upper limb (Table 4). The patient showed moderate improvement in the range of motion of the radiocarpal joint, mainly due to palmar (+8°) and elbow flexion (+3°). At the same time, there was a significant increase in muscle strength, especially in the hand flexors, whose strength increased threefold (+200 %). The strength of the muscles responsible for dorsal (+59.4 %) and elbow flexion (+44.2 %) also increased significantly, indicating a substantial improvement in the functional endurance of the hand.

## Discussion

Although the use of VR technology is more widespread in the rehabilitation of stroke patients [10, 11], in recent years, attention has also been paid to its use as an adjunctive method in the orthopedic profile [12, 13].

A systematic review by A. M. AlHossan et al. [14] included observations involving patients who had undergone rotator cuff repair and compared rehabilitation based on virtual reality with standard physical therapy (6 studies (n ≈ 332 patients) met the inclusion criteria). The authors did not find a statistically significant difference between VR-based rehabilitation and traditional rehabilitation in terms of reducing perceived pain and improving functional outcomes reported by the patients. Nevertheless, their findings showed that VR therapy resulted in a notable enhancement in the overall range of shoulder abduction when compared to conventional rehabilitation methods. However, improvement in shoulder flexion and external rotation did not differ significantly between the groups. Based on the results obtained, it can be concluded that digital rehabilitation can improve patient adherence to the treatment regimen due to greater engagement and accessibility. However, for maximum effectiveness, periodic interaction with clinicians may be necessary. Thus, these results confirm the possibility of incorporating digital health technologies into postoperative rehabilitation protocols for the shoulder, tailored to the individual needs of the patient.

In 2025, several randomized controlled trials were conducted regarding the use of virtual reality in the rehabilitation of individuals with upper limb injuries. S. Prahm et al. [15] conducted a single-center randomized controlled trial with 150 inpatient medical histories, who underwent rehabilitation after traumatic hand injuries using the StableHandVR application (n = 75 intervention group, n = 75 control group). During the assessment, the active range of motion (ROM) of the hand, thumb opposition (Kapanji test), hand flexor strength, upper limb function (DASH), pain (NRS), quality of life (SF-36), usability (SUS), intrinsic motivation (IMI), and training adherence were evaluated. As a result, the intervention group showed a significantly greater improvement in wrist rotation (+27.8° vs. +17.3; $p < 0.001$) and thumb opposition ($p = 0.04$). Pain during movement decreased in both groups. Patients who used StableHandVR voluntarily exceeded the prescribed training volume by 63 %, reporting better perceived effort ($p < 0.001$), usefulness ($p = 0.018$), and excellent usability (SUS = 85.3). Thus, the application of the VR intervention StableHandVR improved motor function recovery, patient engagement in therapy, and adherence to the training regimen, proving its potential for integration into clinical rehabilitation pathways.

S. Kablanoğlu et al. [16] studied the impact of VR-based motor therapy on pain, sensation, quality of life, activity participation, and upper limb function in patients with peripheral nerve injuries of the hand. The study involved 42 individuals (n = 21 intervention group, n = 21 control group). Both groups underwent 30 therapeutic sessions over 6 weeks, consisting of 5 sessions per week, each lasting 60 minutes. In addition to their usual upper limb rehabilitation programs, participants in the intervention group received 30 sessions of VR-based motor therapy (6 weeks, 5 days a week, 20 minutes each). Pain in the upper limbs was assessed using the visual analog scale (VAS), sensory threshold was measured using the Semmes-Weinstein Monofilament Test (5-thread version), hand grip strength was assessed using the Jamar Dynamometer, activity participation was measured using the Quick Disabilities of the Arm,

*Table 4*

**Functional assessment of the left radiocarpal joint of patient B.**

| Indicator | Initial value | Final value |
|---|---|---|
| Goniometry (radiocarpal joint) | Dorsal/palmar flexion: 71°/0°/60°; Ulnar/radial deviation: 29°/0°/43° | Dorsal/palmar flexion: 70°/0°/68°; Ulnar/radial deviation: 32°/0°/44° |
| Dynamometry, kg (radiocarpal joint) | Dorsal flexion: 6.9; Palmar flexion: 11.0; Ulnar flexion: 8.6; Radial flexion: 7.2; Wrist flexors: 8.0 | Dorsal flexion: 11.0; Palmar flexion: 13.8; Ulnar flexion: 12.4; Radial flexion: 11.2; Wrist flexors: 24.0 |

Shoulder, and Hand scale and Duruoz Hand Index, and upper limb functionality was tested using the Jebsen-Taylor Hand Function Test. Quality of life was assessed using the 5-level European Quality of Life (EQ-5D-3L) scale. Statistically significant differences were found between the groups for VAS ($p = 0.001$), Jamar ($p = 0.004$), Quick Disabilities of the Arm, Shoulder, and Hand ($p = 0.015$), and the Duruoz Hand Index ($p < 0.001$) in favor of the intervention group. VR technologies demonstrated a positive effect on reducing pain, improving quality of life, increasing activity levels, and enhancing upper limb function in patients with peripheral nerve injuries of the hand.

The case series presented underscores that the use of VR technologies as an adjunct to traditional rehabilitation significantly improves functional recovery indicators of upper limb movements. Patients not only show positive dynamics in physical measures but also in their psychological and emotional state: they display a high level of engagement in the process, actively collaborate with specialists, and demonstrate consistent motivation for regular sessions. Importantly, after several sessions with VR headsets, patients noted an increase in interest even during the performance of standard physical exercises, which they had previously perceived as monotonous or exhausting. It is worth noting that explaining the VR system to the patient can improve their expectations from rehabilitation [17]. The elements of game-based interaction and the ability to see their own progress in a virtual environment significantly enhance self-esteem and contribute to maintaining a positive mood during treatment [18].

Thus, the results support the effectiveness of VR-based rehabilitation methods in improving upper limb recovery outcomes and can be considered a valuable tool in enhancing patient adherence and motivation during rehabilitation [18].

## Conclusions

The use of virtual reality in the rehabilitation of patients with traumatic upper limb injuries following explosive trauma is an effective adjunctive method. The effectiveness is driven by improved activation of neuromuscular connections, repetitive motor stimuli, and visual feedback provided by the VR environment. The technology enhances motivation, facilitates the execution of exercises, and promotes faster recovery of motor functions. It is important to note that case series studies are a valuable tool for generating knowledge and forming hypotheses but are not suitable for justifying the effectiveness of treatment within the framework of evidence-based medicine. Therefore, further research is needed to study in more detail the effectiveness and optimization of VR technologies in the rehabilitation process. However, the obtained results suggest the feasibility of further integrating VR technologies into clinical rehabilitation practice and developing specialized programs using virtual environments.

**Conflict of interest.** The authors declare no conflict of interest.

**Prospects for further research.** It can be expected that the use of VR headsets as an additional method to standard rehabilitation interventions will be appropriate for increasing motivation for exercise, improving the psychological state, and enhancing patient engagement in the treatment process.

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**Authors' contributions.** Prutula N. Yu., Staude V. A. — justified the relevance of the study, developed the methodology, and selected patients; Subota I. A. — conducted biomechanical studies and analyzed the results; Kuznetsov O. O. — conducted practical sessions with patients; Zemlyana O. V. — literature review and drafting the corresponding section of the text.

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# USE OF VIRTUAL REALITY EYEGLASSES AS AN ADDITIONAL METHOD IN REHABILITATION AFTER UPPER LIMB INJURY

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