

UDC 615.825:616-001.52-057.36
<https://doi.org/10.31612/2616-4868.1.2026.18>

THE ROLE OF INNOVATIVE PHYSICAL REHABILITATION TOOLS IN THE RECOVERY OF AMPUTEE VETERANS

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Abstract

Introduction. Given the emerging challenges associated with the ongoing conflict, the implementation of innovative rehabilitation approaches is imperative to preserve military personnel's combat morale and facilitate their successful reintegration into civilian society.

Aim. To review and synthesize scientific research on innovative rehabilitation methods for military personnel, including state-of-the-art prosthetic technologies, and assess their impact on physical and psychological recovery.

Materials and methods. This study presents a comprehensive analysis and generalization of current scientific literature, guidelines, and expert recommendations related to the justification and implementation of medical and social rehabilitation strategies for military personnel who have undergone limb amputation due to combat-related injuries during the war in Ukraine.

Results. The full-scale war in Ukraine, which began in 2022, has served as a powerful catalyst for the development and integration of innovative technologies in medical rehabilitation, particularly in the field of prosthetics. The widespread occurrence of traumatic injuries among military personnel, especially limb amputations, has created an urgent demand for high-tech solutions aimed at restoring lost functionality. In response to these challenges, domestic and international scientific and engineering communities have intensified efforts to develop advanced prosthetic systems based on bioengineering, robotics, neurotechnology, and additive manufacturing achievements.

Particular attention has been given to the development of bionic prostheses capable of not only morphologically replicating lost limbs but also restoring their functional capabilities through the use of sensory systems, neural interfaces, and machine learning algorithms. The integration of cutting-edge technologies into prosthetics is regarded as a promising direction in rehabilitation medicine, contributing to improved quality of life and full social reintegration of affected individuals.

Conclusions. Innovative approaches to the rehabilitation of military personnel after limb amputation and prosthetics occupy a key position in modern medical practice. The effectiveness of the rehabilitation process is ensured through a comprehensive approach that includes physical therapy, psychological support, social integration measures, and the application of high-tech solutions.

Keywords: technical rehabilitation aids, individualized rehabilitation strategies, prosthetics, functional adaptation, military personnel

INTRODUCTION

With the onset of Russia's full-scale invasion of Ukraine in 2022, the rehabilitation of service members

who have sustained severe injuries, particularly limb amputations, has become a matter of critical importance. Ukraine is actively implementing innovative measures to assist these patients, including advanced prosthetic

technologies and multidisciplinary rehabilitation approaches [1, 2].

The country has also developed its rehabilitation centers, such as the Unbroken Center in Lviv, where teams of surgeons, orthopedic specialists, neurorehabilitation experts, and psychologists collaborate. These centers employ individualized recovery programs that encompass physiotherapy, prosthetic training, and adaptation to new life circumstances. Special emphasis is placed on integrating patients into daily life and on training them to use high-tech prostheses, such as bionic devices, to ensure maximum functionality and comfort [3, 4].

A substantial increase in the number of service members undergoing limb amputations as a result of explosions, mines, and other combat-related injuries has heightened the urgency of researching innovative rehabilitation and prosthetic solutions. In Ukraine, several specialized medical centers have been established, such as the «Unconquered» Center in Lviv and the Superhumans Center in Kyiv, which not only manufacture prostheses but also provide social reintegration and psychological support for military personnel [5, 6].

Innovative methods include the use of virtual reality (VR) and augmented reality (AR) technologies to restore motor function, interactive training programs with real-time virtual feedback, and intelligent patient-monitoring systems. Both Ukrainian and international companies are working to refine prosthetic devices that not only replicate lost functions but also interface with the user's nervous system, offering sensory feedback and thought-based control [6, 7].

In light of the new challenges posed by the ongoing conflict, innovative rehabilitation methods are essential both to preserve soldiers' morale and to support their successful reintegration into society. The current situation requires a comprehensive, multidisciplinary response to these issues, backed by adequate support from government bodies, industry partners, and non-governmental organizations [8, 9, 10].

AIM

To review and synthesize scientific research on innovative rehabilitation methods for military personnel, including state-of-the-art prosthetic technologies, and to assess their impact on both physical and psychological recovery.

MATERIALS AND METHODS

An analysis and synthesis were conducted of scientific articles, guidelines, and recommendations on the rationale for and implementation of medical and social rehabilitation processes for military personnel who have undergone limb amputation during combat operations in Ukraine.

RESULTS AND DISCUSSION

Advances in Prosthetic Technology. Modern prosthetic technologies are rapidly evolving, driven in large part by innovations in bionic prostheses, 3D printing of limbs, and the use of nanomaterials. The war in Ukraine, which began in 2022, has served as a significant catalyst for refining and introducing these cutting-edge technologies into medical practice, particularly prosthetics, given the large number of service members who have sustained severe injuries requiring advanced restorative solutions [7, 11, 12].

Bionic prostheses represent the most advanced devices designed to replicate the functions of lost limbs. Equipped with specialized sensors and computer microchips, these prostheses not only provide an aesthetic appearance but also enable the restoration of specific hand or foot functions. Modern bionic prostheses allow users to perform complex movements, such as grasping and holding objects, and in some cases support specialized actions, including lifting heavy weights or executing precise manipulations [12, 13, 14].

One of the most revolutionary technologies in prosthetics is 3D printing. This method allows for the creation of custom prostheses using computer models that precisely meet each patient's needs. 3D printing enables the fabrication of lightweight, durable, and user-specific devices – including entire limb components – thereby significantly easing rehabilitation and improving quality of life. Because 3D printing can employ a variety of materials, including light metal alloys and polymers, these prostheses are becoming increasingly accessible to a broader population [15].

The use of nanomaterials has also emerged as a key direction in the development of new prosthetic devices. Nanomaterials can greatly enhance a prosthesis's strength and longevity while making it lighter and more comfortable to wear. Incorporating nanoparticles into prosthetic materials provides high thermal resistance, wear resistance, and improved biocompatibility – critical factors for patients who rely on their prostheses continuously [16].

Since 2022, the conflict in eastern Ukraine has driven an increased demand for these innovative technologies, as the number of wounded service members requiring modern prostheses rose significantly. Both domestic and international prosthetics manufacturers have mobilized to address this need. Consequently, a range of initiatives was launched to deploy cutting-edge prosthetic technologies for injured military personnel, enabling them not only to restore physical mobility but also to reintegrate into social life [7, 8].

Prosthetics incorporating bionic technologies, 3D printing, and nanomaterials not only streamline the rehabilitation process but also provide patients with new opportunities for social integration. These technologies support physical recovery and promote psychological

adaptation by restoring individuals' sense of capability and normalcy following injury [16, 17].

Innovative prosthetic approaches implemented in Ukraine under wartime conditions are opening new horizons in medical rehabilitation and assisting thousands of affected individuals by enabling their return to normal life [18].

Since Russia's full-scale invasion of Ukraine in 2022, prosthetics has become a key area of development, particularly in addressing the needs of veterans and civilians injured by the conflict. Ukrainian prosthetics startups have drawn considerable attention with their innovative designs, which aim to improve the quality of life for those who have lost limbs. The high number of combat-related injuries created an urgent demand for high-technology prostheses that could not only restore physical ability but also support psychological rehabilitation [19]. One of the main challenges faced by these Ukrainian startups has been ensuring both the accessibility and efficacy of new prosthetic technologies, as well as securing adequate funding for their projects. Nonetheless, post-war demand for high-quality prostheses has continued to grow, driving the expansion of these enterprises.

Many Ukrainian startups have focused on innovative technologies, particularly the use of 3D printing to produce custom prostheses. This technology enables the creation of lightweight, comfortable devices that precisely match each patient's anatomical features. As a result, production times have been significantly reduced and material costs lowered, making these prostheses more accessible to a broader population [20].

Other key developments include bionic prostheses equipped with sensors and microprocessors, which allow patients not only to regain motor function but also to access advanced features such as nerve-impulse-based control. These innovations open new possibilities for rehabilitation and adaptation to post-injury life [12, 14].

Despite these significant achievements, Ukrainian startups face a range of challenges, including limited manufacturing infrastructure, the need for highly skilled personnel, and substantial R&D expenses. Nevertheless, many projects receive support from government bodies, international organizations, and charitable foundations, enabling the continued development of innovative prosthetic solutions (Table 1).

Table 1

Major Ukrainian Startups in the Field of Prosthetics

Startups	Project Description	Technologies and Innovations	Prospects
Prosthetics4Life	Fabrication of custom prostheses using 3D printing	Use of 3D printing for prosthesis production with rapid patient-specific adaptation	Expansion of manufacturing capacity and collaboration with medical institutions
BioProsthetics	Implementation of neural-controlled bionic limb technologies	Neuro-controlled bionic limb systems	Advancing neural interface technology and designing next-generation prosthetics
3D Prosthetic Solutions	Firm specializing in 3D-printed lightweight prosthetic devices	3D printing, lightweight materials, rapid prosthetics production	Expanding manufacturing and collaborating with nonprofit organizations to lower prices
InnoProsthetics	Integration of bionic technologies with modern materials for prosthetics manufacturing	High-tech bionic prostheses equipped with sensors and microprocessors	Improvement of prosthetics, cost reduction, and increased accessibility
Kukubara Technologies	Development of interactive prostheses for active users facing high physical demands	Interactive prostheses specializing in athletes and other highly active individuals	Distribution among sports communities and market expansion for active amputees

Source: author's Tkachuk A. V. compilation.

Since Russia's full-scale invasion of Ukraine in 2022, the adaptation of prostheses for combat conditions has become critically important. The conflict has resulted in a large number of service members requiring prosthetic limbs following amputation. This, in turn, has driven the development of new technologies capable of meeting the specific rehabilitation and adaptation needs of soldiers operating in demanding combat environments. Consequently, there has been a need to create specialized prostheses that can withstand high physical stress and provide maximum mobility in extreme situations [20].

Successful adaptation of prosthetic devices to such conditions requires the integration of advanced material technologies, engineering solutions, and a personalized approach for each patient. Prostheses must

be as comfortable and lightweight as possible, yet durable enough to withstand high loads and the demands of military operations. Key requirements include impact resistance, waterproofing, adaptability to various weather conditions, and a high level of user comfort to facilitate normal activity following injury [20, 21].

One of the crucial aspects is that prostheses must be adapted for use in military operations, where they may be subjected to intense physical demands. Specialized prostheses for military personnel should be designed not only for walking but also for participation in combat activities, such as navigating difficult terrain, rapid movement, using specialized equipment, and performing other tasks. Since 2022, Ukraine has actively implemented new approaches to prosthetics, particularly through the

use of advanced materials such as carbon fiber, titanium, and specialized alloys, which provide strength and lightness to the prostheses. Notably, the development of bionic technologies has enabled the creation of prostheses capable of mimicking the movements of natural limbs, significantly improving patients' quality of life [22].

An important element in the adaptation process is the psychological aspect. Military personnel who have undergone amputation face serious emotional and psychological challenges, so an essential part of prosthesis adaptation is providing emotional support, training patients in the use of new devices, as well as offering psychological assistance to overcome stress and return to normal life [23, 24].

Considering the experience of recent years, especially after the war in 2022, Ukraine has been actively developing programs that help veterans go through the adaptation process to new life conditions. One of the key directions is the creation of specialized prosthetics and rehabilitation centers that provide comprehensive support for military personnel. These centers offer both technical assistance in the manufacture and fitting of prostheses, as well as psychological and physical rehabilitation, enabling a successful return of servicemen to active life.

The psychological aspect of prosthetics is no less important than the physical one. Patients who have undergone amputation often face challenges adapting to new capabilities, struggling with depression, and experiencing social isolation. In prosthetics centers such as «Superhumans» (Kyiv), patients receive comprehensive support, including psychological counseling, which helps them adapt to new life realities [25].

It is worth noting that modern prosthetic methods, such as osseointegration, also have psychological effects. Patients who choose this method report an improved quality of life and a sense of «regaining» their lost limbs. However, this method is not suitable for everyone, and the decision to use it must be made individually, taking into account medical indications and the patient's psychological readiness [8].

Innovative Technologies in Rehabilitation. Since the full-scale war began in Ukraine in 2022, the rehabilitation of servicemen has undergone significant changes thanks to the introduction of modern technologies such as virtual reality (VR) and robotics. These innovations contribute to more effective restoration of motor functions, treatment of PTSD, and acquisition of new skills [26, 27].

Virtual reality has become a powerful tool in the rehabilitation of military personnel. In particular, psychologists at the First Volunteer Surgical Hospital in Ivano-Frankivsk use VR headsets to establish quicker contact with patients and to treat stress and PTSD. This technology helps improve concentration and provides emotional relief while teaching self-regulation skills.

Additionally, since summer 2022, volunteers from the Art Therapy Force project have been assisting

medical institutions in implementing VR as an auxiliary rehabilitation tool, which helps improve the psycho-emotional state of patients.

Robotics plays a significant role in the physical rehabilitation of military personnel. The implementation of rehabilitation exoskeletons and automated training devices enhances the restoration of motor functions and improves the overall effectiveness of the rehabilitation process [28, 29]. For instance, at the RECOVERY medical center, operating under the Ministry of Internal Affairs, training sessions have commenced for over 70 rehabilitation specialists who work directly with service members. This demonstrates the active integration of cutting-edge methods and technologies into the rehabilitation system.

It is important to note that the integration of VR and robotics into the rehabilitation of Ukrainian military personnel is provided free of charge for both active-duty soldiers and veterans. These technologies are incorporated into supplementary therapy programs aimed at enhancing the physical and psychological well-being of patients [26, 29].

The integration of virtual reality and robotics into the rehabilitation process contributes to more efficient and accelerated recovery of military personnel, helping them return to a full life [30, 31]. Modern technologies – particularly artificial intelligence, telemedicine, and biotechnology – play a key role in enhancing rehabilitation programs and ensuring effective support for veterans.

Artificial intelligence technologies promote the personalization of rehabilitation programs and enable ongoing monitoring of patient progress. AI facilitates the analysis of large volumes of health data, allowing for the development of individualized rehabilitation plans tailored to the specific needs of each veteran. Additionally, AI can track recovery dynamics, detect potential complications, and adjust therapeutic interventions promptly. In Ukraine, several projects aimed at integrating AI into the military sector are already underway, highlighting the potential of these technologies in veteran rehabilitation [32, 33].

Telemedicine provides remote access to rehabilitation services, which is especially important for veterans living in remote areas or those with limited mobility. The use of telemedical platforms enables consultations, health monitoring, and even certain therapeutic interventions without the need for the patient's physical presence at a medical facility. This enhances both the accessibility and quality of medical services for veterans [34].

Biotechnologies open up new possibilities for tissue regeneration and the treatment of damaged muscles. The use of stem cells allows for the stimulation of damaged tissue regeneration, which accelerates the recovery process and improves rehabilitation outcomes. Additionally, advanced methods for treating scars and muscle injuries contribute to better functional status and quality of life for patients [12].

Information platforms for veterans, particularly mobile applications, are becoming essential tools in planning rehabilitation and monitoring health. Such apps can provide information about available rehabilitation programs, reminders to take medications, options to track personal progress, and access to support from veteran communities. For instance, in Ukraine, educational online courses are being implemented to help veterans adapt to civilian life, demonstrating the importance of digital solutions in supporting veterans [10, 23, 24, 25].

In the post-invasion period after 2022, Ukraine has been actively implementing digital technologies for recovery and development across various sectors, including veteran rehabilitation. The Digital Development and Innovation Strategy until 2030 envisions the use of autonomous technologies and artificial intelligence to improve the quality of life for citizens [35].

Overall, the integration of modern technologies into rehabilitation programs enhances the effectiveness of veterans' recovery by ensuring an individualized approach, accessibility of services, and the use of advanced treatment methods.

Prosthetic training. Rehabilitation of military personnel after limb amputation and subsequent prosthetic fitting is a complex and multifaceted process that requires a comprehensive approach to restore physical abilities and achieve psychological adaptation. After amputation, the initial priorities include stump formation, prevention of contractures, and anti-edema therapy. These measures help prepare the individual for prosthetic fitting and create optimal conditions for further rehabilitation [36].

Learning to use a prosthesis is a critical stage of rehabilitation. It involves both theoretical knowledge and practical skills aimed at integrating the prosthesis into the patient's daily life. Special attention is given to training hand-eye coordination, which ensures the safe and effective use of the prosthesis [37].

Adaptation to bionic prostheses requires a specialized approach. Bionic prostheses restore mobility and fine motor skills, enabling complex movements such as grasping small objects or performing manual tasks. For effective adaptation, continuous support from medical professionals and family members is essential, including regular consultations and adjustments to the prosthesis settings.

Modern technologies such as virtual reality (VR) are increasingly being implemented in prosthetic training. The use of VR technology allows patients to simulate different situations and practice skills in a safe environment, which facilitates faster adaptation and boosts patients' confidence in using the prosthesis.

Improving coordination and endurance is a key aspect of rehabilitation. Specially designed training programs include exercises to strengthen muscles, develop balance, and enhance overall physical fitness. For example, programs for individuals with lower limb amputations may include plank variations, supine exercises, crunches, and stretching routines using the prosthesis.

A comprehensive rehabilitation approach that combines physical therapy, psychological support, and modern technologies enables service members after amputation to regain active lifestyles and reintegrate as full members of society [37].

Innovative Technologies in Recovery. The rehabilitation of service members after limb amputations and prosthetic fitting is a vital aspect of modern medicine, especially in the context of armed conflicts. Innovative technologies play a key role in restoring functional capabilities and improving the quality of life.

One promising direction is the use of neural interfaces to control prosthetic limbs. These systems integrate the human nervous system with the prosthesis, enabling natural and intuitive control (Table 2).

Table 2

Examples of Innovative Technologies in the Rehabilitation of Military Personnel after Limb Amputations and Prosthetic Fitting

Technology	Description	Application example
Neurointerfaces for prosthesis control	Use of electrodes to read nerve impulses and transmit them to the prosthesis	Prostheses by Össur with a neural control system
Remote control of prostheses	Specialized mobile applications for configuring and controlling the operation of prostheses	Apps for controlling bionic hands by Touch Bionics
Implantable biomechanical systems	Use of biocompatible materials and integration of sensors for transmitting tactile sensations	Bionic hands with tactile feedback from BrainRobotics
3D printing of prostheses and implants	Manufacturing of prostheses and implants based on the individual parameters of the patient	Use of 3D printing for facial reconstruction at «Imatech Medical»
AI- and machine learning-powered prostheses	Automatic adjustment of prosthesis movements to the user thanks to artificial intelligence	Smart prostheses by Esper Bionics
Virtual reality in rehabilitation	Use of VR for training family members in managing prostheses	Rehabilitation programs: Phantom Limb Therapy

Source: author's Tkachuk A. V. compilation.

Neural interfaces read electrical signals from the brain or nerve endings, converting them into commands for the prosthesis, allowing patients to perform complex movements and receive feedback. Remote control of prostheses via mobile applications is another innovation that simplifies the adjustment and management of prostheses. Using specialized apps, users can change prosthesis operating modes, monitor its condition, and receive usage recommendations. This enhances their autonomy and aids in faster adaptation to new conditions. The development of implanted biomechanical systems opens new horizons in prosthetics [38].

Modern research is focused on creating prostheses that not only imitate the external limb but also reproduce its functional capabilities. The use of biocompatible materials and the integration of sensory systems allow patients to feel touch, temperature, and other tactile sensations, significantly improving quality of life. In Ukraine, modern technologies are also actively being implemented in the rehabilitation of military personnel. For example, the «Imatech Medical» clinic in Kyiv uses 3D printing for the reconstruction of the faces of wounded soldiers. With the help of 3D printers, implants and prostheses are created to restore damaged areas, which facilitates faster and more effective rehabilitation [21].

Thus, modern innovative technologies significantly expand the possibilities for the rehabilitation of military personnel after amputations and prosthetics, providing them with a fuller and higher-quality life [39, 40].

DISCUSSION

The analysis highlights the vital role of adopting innovative technologies in the physical rehabilitation of military personnel following limb amputations. Since the full-scale war in Ukraine started in 2022, the number of patients requiring advanced prosthetics and tailored recovery programs has increased rapidly. This situation has served as a strong catalyst for actively incorporating modern solutions into clinical rehabilitation practices [7-10].

Of particular significance is the integration of bionic prostheses with neural interface systems, which enables precise movement and offers sensory feedback. The study by Salminger et al. (2022) [13] showed that such advanced systems greatly enhance prosthesis acceptance and support patients' psychological adjustment. In Ukraine, these technologies are already in use not only in leading rehabilitation centers like «Superhumans» and «Unbroken,» but also in private initiatives, including startups such as Prosthetics4Life, BioProsthetics, and InnoProsthetics [20].

Another key aspect is the adoption of 3D printing technologies in prosthetic manufacturing. Unlike traditional methods, additive manufacturing enables customization

of the prosthetic design based on the patient's anatomy, reduces the overall weight of the device, lowers production costs, and accelerates rehabilitation [14, 15, 21]. The study by Tran et al. (2022) [14] demonstrated that combining 3D printing with biomechanical modeling allows for high precision in replicating joint functionality, especially in the knee and ankle. In Ukraine, this technology is particularly relevant due to the urgent need to respond swiftly to the rising number of cases caused by combat injuries [20].

Equally important is the focus on psychological rehabilitation and social reintegration for individuals who have undergone amputation. Sources [23-25] confirm that post-amputation patients often experience depression, low self-esteem, social isolation, and difficulty returning to active life. Innovative methods such as virtual reality (VR) therapy and art therapy in immersive environments are playing a significant role in addressing these issues. Data from Küçüktabak E. B. et al. (2021) [40], along with findings from volunteer initiatives in Ukraine, show that VR sessions can not only reduce anxiety levels but also activate the motor cortex during the process of learning to use a prosthetic limb.

Particular attention should be paid to the use of rehabilitation exoskeletons and robotic systems, which have been proven effective in restoring motor functions in patients with amputations [28, 29]. The study by Molteni F. et al. (2018) [31] confirms that exoskeletons can significantly enhance gait, balance, and overall lower limb functionality. When combined with virtual reality, these technologies create a novel approach to motor training based on biofeedback and the simulation of natural movements. In Ukraine, such methods are already being used, especially at the RECOVERY center, which operates under the Ministry of Internal Affairs' medical institutions, where more than 70 physical therapy specialists are training to use VR and exoskeletons [29].

Another promising area is the development of implantable biomechanical systems that include tactile feedback mechanisms with artificial intelligence. Next-generation prosthetic devices, such as bionic hands developed by BrainRobotics, not only replicate movement but also enable users to perceive temperature, touch, and texture, thereby approximating the natural sensory experience [38]. These technologies offer not only functional capabilities but also sensory integration, greatly enhancing the patient's emotional perception of the prosthesis.

The integration of artificial intelligence (AI) into physical rehabilitation systems opens new possibilities for personalized medicine. According to Küçüktabak E. B. et al. (2021) [40], using machine learning algorithms in prosthetic control allows for automatic adjustment of prosthetic movements to match the patient's habitual motor patterns. This greatly reduces fatigue during prosthesis use and shortens the adaptation period. In

wartime conditions, where rehabilitation efficiency and speed are critically important, such systems show significant value. Ukrainian startups are already actively creating similar solutions, for example, Esper Bionics, where AI enables the prosthesis to self-learn and adapt based on the user's movement patterns [40]. An additional benefit is the use of telemedicine platforms in the rehabilitation process. These platforms support remote consultations, enable monitoring of rehabilitation program compliance, and help maintain psycho-emotional contact with the patient, even when the individual is in remote or hard-to-reach areas [34]. Given the challenges related to patient displacement in combat zones or temporarily occupied territories, telerehabilitation is emerging as one of the most promising areas for further growth.

Although significant progress has been made, effective implementation of innovations in the rehabilitation system for military personnel after amputations still encounters several challenges. First, there is an infrastructure gap: even in leading Ukrainian clinics, there is a shortage of specialized equipment, properly adapted facilities, and enough qualified staff [23, 24]. These issues often restrict access to advanced prosthetics, especially for patients from rural areas.

Second, a gap persists between needs and funding. As reports from the Ministry of Health of Ukraine and IREX project studies [10, 25] show, the current cost of care per patient significantly exceeds the average budget for rehabilitation programs. This situation requires greater involvement from the government, along with increased investment from international donors and civil society organizations.

Third, standardizing rehabilitation protocols remains a challenge, especially when it involves integrating physical therapy, neurorehabilitation, and psychosocial support. Although clinical guidelines exist (e.g., from the Ministry of Health and international recommendations [19, 23]), a unified rehabilitation pathway system that ensures consistent quality of care nationwide does not currently exist. A positive development is the expansion of digital platforms, mobile apps, and online educational courses that help veterans understand their rights, access treatment options, and find available support resources [10, 35]. These tools serve not only as information sources but also as ways to monitor health, gather patient feedback, and reduce anxiety during waiting periods for assistance.

Ultimately, a person-centered approach is crucial, emphasizing the development of individualized rehabilitation plans that consider the patient's psychological and emotional well-being, as well as their social environment. As noted by authors in references [36-37], comprehensive programs that integrate physical, cognitive, and emotional components yield the best results in adapting to life with a prosthesis. In

conclusion, examining innovative rehabilitation tools shows that the future of this field depends not only on technological advancements but also on building an interdisciplinary system capable of supporting the patient through every stage – from amputation to full social reintegration. For Ukraine, which continues to endure a prolonged state of war, developing such systems is not a luxury but an absolute necessity.

CONCLUSIONS

1. Innovative rehabilitation methods for military personnel after limb amputations and prosthetics are an important component of modern medicine, contributing to the restoration of functionality and improvement of quality of life. In this context, special attention is given to physical rehabilitation, psychological support, social adaptation, and the implementation of modern technologies in the rehabilitation process.

2. The introduction of innovative technologies, such as 3D printing of custom prostheses and electronically controlled prosthetics, has significantly improved the quality of prostheses, making them more functional and comfortable for users.

3. Innovative rehabilitation methods for military personnel after limb amputation and prosthetics constitute a complex process that requires the integration of medical, psychological, and social approaches.

Prospects for Further Research. A promising avenue for future scientific investigation lies in the development and integration of advanced technologies in prosthetics and rehabilitation. These technologies demonstrate rapid adaptability to evolving conditions and significantly enhance functional outcomes. Ukrainian startups specializing in prosthetic development are experiencing dynamic growth, positioning the sector for considerable advancement. Despite ongoing challenges related to funding limitations and infrastructural constraints, these enterprises play a critical role in the restoration of health and functional capacity of veterans and other individuals affected by armed conflict. With continued support from governmental bodies, international organizations, and civil society initiatives, the Ukrainian prosthetics industry has the potential to emerge as a globally leading innovator.

COMPLIANCE WITH ETHICAL REQUIREMENTS

This review article is based on analyzing publicly available scientific materials published in peer-reviewed journals, clinical guidelines, and databases. No patient-identifiable data were used in the course of this work, nor was ethical committee approval required, as the study did not involve new clinical interventions or primary collection of patient data. The authors adhered to the

ethical standards outlined in international publication guidelines for medical journals, particularly the ICMJE recommendations. All elements of the work are original and free from plagiarism or data fabrication. All information sources have been properly cited and formatted by the relevant requirements.

The authors declare compliance with the Helsinki Declaration of the World Medical Association – «Ethical Principles for Medical Research Involving Human Subjects» – in the conduct of these studies, and confirm that there have been no breaches of ethical norms in the scientific research.

Conducting the research does not contradict the norms of Ukrainian legislation and meets the requirements of the Law of Ukraine «On Scientific and Scientific-Technical Activities» dated November 26, 2015, No. 848-VIII.

FUNDING AND CONFLICT OF INTEREST

The authors declare no conflict of interest regarding this article. No external funding was provided for this study.

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Резюме

РОЛЬ ІННОВАЦІЙНИХ ЗАСОБІВ ФІЗИЧНОЇ РЕАБІЛІТАЦІЇ У ВІДНОВЛЕННІ ВІЙСЬКОВИХ ПІСЛЯ ПРОТЕЗУВАННЯ
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Вступ. У зв'язку з новими викликами війни, інноваційні методи реабілітації є необхідними для збереження бойового духу солдатів, а також для їх ефективної реінтеграції у суспільство.

Мета. Узагальнення наукових досліджень щодо аналізу інноваційних методів реабілітації військових, що включають новітні технології в області протезування, а також оцінка їхнього впливу на фізичну та психологічну реабілітацію.

Матеріали та методи. Проведено аналіз та узагальнення наукових статей, настанов та рекомендацій щодо обґрунтування та запровадження процесів медичної та соціальної реабілітації військових, які пережили ампутацію кінцівок під час бойових дій в Україні.

Результати. Війна в Україні, яка розпочалася в 2022 році, стала важливим каталізатором для вдосконалення та впровадження новітніх технологій у медичну практику, зокрема в протезуванні, оскільки значна кількість військовослужбовців отримала важкі травми, що потребували застосування новітніх технологій відновлення. Сучасні технології у протезуванні активно розвиваються завдяки інноваціям у галузі біонічних протезів, 3D-друку кінцівок та використанню наноматеріалів. Новітні розробки спрямовані на створення протезів, які не лише імітують втрачені кінцівки, але й відтворюють їх функціональні можливості.

Висновки. Інноваційні підходи до реабілітації військовослужбовців після ампутацій кінцівок та протезування посідають ключове місце в сучасній медичній практиці. Комплексний підхід, що включає фізичну реабілітацію, психологічну підтримку, соціальну адаптацію та використання високотехнологічних рішень, забезпечує суттєве підвищення якості життя пацієнтів та сприяє їх ефективному поверненню до активної діяльності. Особливої уваги заслуговує впровадження новітніх технологій, зокрема адитивного виробництва (3D-друку) індивідуалізованих протезів та протезних конструкцій з електронним керуванням, що значно розширюють функціональні можливості користувачів і відповідають сучасним стандартам персоналізованої медицини.

Ключові слова: технічні засоби реабілітації, індивідуалізовані реабілітаційні стратегії, протезування, функціональна адаптація, військовослужбовці

Received: 18.11.2025

Accepted: 30.01.2026