Robotics in the medicine of the future: treatment and rehabilitation

Robótica en la medicina del futuro: tratamiento y rehabilitación

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Highlights

- Robotic rehabilitation significantly improved motor function, endurance, and coordination after stroke, confirming its effectiveness as a complementary method to traditional therapy in Ukrainian clinics.
- Variability in outcomes highlights the importance of patient condition, timing, and therapy intensity, with moderate impairment showing stronger progress than severe cases.
- The study underscores both the therapeutic benefits and financial barriers of robotic systems, emphasizing the need for standardized protocols, long-term evaluation, and wider accessibility.

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ABSTRACT

Introduction. The growing demand for effective post-stroke rehabilitation has accelerated the integration of robotic systems incorporating artificial intelligence and sensor technologies into clinical practice. **Objective.** To evaluate the effectiveness of robotic systems in the rehabilitation of patients with ischemic stroke in Ukrainian clinics. **Materials and Methods.** A controlled experimental study was conducted with 62 patients randomly assigned to control (conventional physiotherapy) and experimental (physiotherapy plus robotic-assisted therapy) groups. Robotic exoskeletons and sensor-based simulators were used. Outcomes were assessed using validated tools: Fugl-Meyer Assessment (FMA), Timed Up and Go (TUG), and 6-Minute Walk Test (6MWT). Adaptive algorithms adjusted therapy intensity to individual needs. **Results.** The experimental group showed greater improvement compared with the control group, with a mean increase of 6.63 points on the FMA scale, a reduction of 4.17 seconds in TUG time, and an increase of 44.47 meters in 6MWT distance. Improvements were statistically significant ($p < 0.05$) and consistent with international evidence supporting early and intensive rehabilitation. However, the relatively small sample size and short follow-up period limit generalizability. **Conclusions.** Robotic-assisted rehabilitation significantly enhances motor function, endurance, and functional mobility after stroke. These findings support its integration as a complementary strategy within clinical rehabilitation protocols. Further multicenter studies with long-term follow-up are needed to standardize protocols and evaluate sustainability of outcomes.

RESUMEN

Introducción. La creciente demanda de rehabilitación eficaz posterior al ictus ha impulsado la incorporación de sistemas robóticos que integran inteligencia artificial y tecnologías sensoriales en la práctica clínica. **Objetivo.** Evaluar la efectividad de los sistemas robóticos en la rehabilitación de pacientes con ictus isquémico en clínicas de Ucrania. **Materiales y métodos.** Se realizó un estudio experimental controlado con 62 pacientes asignados aleatoriamente a un grupo control (fisioterapia convencional) y un grupo experimental (fisioterapia más terapia robótica asistida). Se emplearon exoesqueletos robóticos y simuladores con retroalimentación sensorial. Los resultados se evaluaron mediante la Fugl-Meyer Assessment (FMA), la prueba Timed Up and Go (TUG) y el 6-Minute Walk Test (6MWT). Algoritmos adaptativos ajustaron la intensidad del tratamiento según las necesidades individuales. **Resultados.** El grupo experimental presentó mayores mejoras respecto al control, con un aumento promedio de 6,63 puntos en la escala FMA, una reducción de 4,17 segundos en el TUG y un incremento de 44,47 metros en el 6MWT. Las diferencias fueron estadísticamente significativas ($p < 0{,}05$) y coherentes con la evidencia internacional que respalda la intervención temprana e intensiva. El tamaño muestral reducido y el corto seguimiento limitan la generalización. **Conclusiones.** La rehabilitación robótica mejora significativamente la función motora, la resistencia y la movilidad funcional tras el ictus. Se recomienda realizar estudios multicéntricos con seguimiento prolongado para estandarizar protocolos y evaluar la sostenibilidad de los resultados.

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INTRODUCTION

Modern medicine is undergoing a global transformation in which digital technologies, artificial intelligence, and robotics are becoming key factors in improving treatment outcomes and rehabilitation effectiveness. The increasing prevalence of cardiovascular and neurological diseases, including stroke, as well as musculoskeletal injuries, is generating growing demands on healthcare systems to ensure not only survival but also rapid and high-quality functional recovery. In this context, the integration of robotic solutions into rehabilitation protocols represents one of the most significant scientific and practical challenges in contemporary medicine.

An analysis of current scientific works shows that robotic systems provide a significant increase in motor function and quality of life of patients, demonstrating advantages over traditional physiotherapy[(1,2)]. Developments in the field of exoskeletons for the upper and lower extremities are opening up new possibilities for personalized therapy, allowing for shorter recovery times after stroke or injury[(3,4)]. Studies also show the effectiveness of robotic technologies in pediatric rehabilitation for cerebral palsy, especially when combined with gamified and virtual tools that increase patient motivation[(5-7)]. A separate area is the integration of robotic devices with artificial intelligence systems and sensors, which ensures the adaptability of programs and more accurate monitoring of patient progress[(8-10)].

Despite the obvious achievements, significant gaps remain in this area. There is a lack of uniform standards for the clinical use of robotic systems, as well as a shortage of long-term longitudinal studies and multicenter trials that would enable the development of universal rehabilitation protocols[(11–13)]. Unequal access to innovative technologies also remains problematic, since their high cost and the need for specialized personnel limit widespread adoption, particularly in regional medical facilities[(14–16)].

Recent advancements highlight the integration of robotic rehabilitation systems with virtual and sensory environments, enhancing patient engagement and functional recovery[(17–19)]. At the same time, the high prevalence of comorbid conditions such as hypertension, diabetes, and cognitive impairment significantly influences rehabilitation outcomes after stroke, underscoring the need for adaptive and personalized robotic protocols that account for complex clinical profiles[(20–24,35)].

Although numerous international studies have been conducted, the evidence remains fragmented, and unified protocols adapted to specific healthcare systems are still lacking. This research addresses this gap by examining the clinical effectiveness and feasibility of integrating robotic systems into rehabilitation practice in Ukraine, where economic and infrastructural constraints pose additional challenges for standardization and implementation.

Medicine is undergoing a global transformation in which digital technologies and robotics are becoming key tools for enhancing treatment precision, patient monitoring, and post-stroke recovery[(1,8,12,25)]. This technological shift has stimulated the emergence of an interdisciplinary field combining engineering, neuroscience, and clinical rehabilitation, where robotics serves as a bridge between medical science and technological innovation. Such integration allows clinicians to achieve higher precision, reproducibility, and personalization in therapy, addressing the limitations of manual physiotherapeutic techniques[8,25].

Studies of exoskeletons for the lower and upper extremities demonstrate advantages over traditional approaches, particularly in restoring gait and hand motor function[3,4,26,27]. Special attention has been given to pediatric neurorehabilitation in children with cerebral palsy, where robotic systems combined with gaming and gamified technologies have shown high effectiveness and increased patient motivation[5–7,28].

Current research identifies several strategic directions in medical robotics: post-stroke limb rehabilitation using exoskeletons and robotic simulators; pediatric neurorehabilitation; integration of robotics with virtual and augmented reality; and home-based rehabilitation supported by mobile robotic systems and remote control technologies[25,29–31]. Exoskeleton-based and sensor-assisted systems have demonstrated positive effects on movement coordination and motivation in children with cerebral palsy and in orthopedic recovery, while the combination of robotic simulators with virtual or augmented reality environments further enhances engagement and cognitive stimulation[7,8,14].

These developments reflect the interdisciplinary nature of medical robotics and its progression toward personalized, accessible, and data-driven therapy.

In addition, research highlights the synergy between robotics and digital innovations such as virtual reality, artificial intelligence, and sensor systems, which enhance adaptability and personalization of rehabilitation programs[8-10,29]. According to recent classifications, rehabilitation robotics includes several types: lower- and upper-limb exoskeletons providing mechanical support and guided movement; robotic simulators with biofeedback for precise control and coordination; gamified and virtual-reality systems designed to increase engagement and motivation; and AI-driven, sensor-based devices capable of adapting load and movement trajectories according to individual performance[9,15,26,29]. This diversity reflects the increasing complexity and personalization of robotic rehabilitation tools and supports their growing clinical adoption.

The practical effectiveness of these systems was further demonstrated during the COVID-19 pandemic, particularly in home-based rehabilitation settings, highlighting the potential of mobile robotic technologies[14–16,30]. At the same time, researchers emphasize the need for protocol standardization and careful consideration of limitations related to treatment intensity, accessibility, and long-term outcomes[11,13,31,32]. Meta-analytical evidence consistently reports that robotic rehabilitation improves motor strength, coordination, and walking performance compared with conventional physiotherapy, especially when initiated early and delivered with sufficient intensity[13,31,34]. However, results vary due to device heterogeneity, differences in intervention duration, and patient engagement levels, and long-term superiority over conventional therapy remains uncertain because follow-up data beyond 6–12 months are limited[11,33,34]. These findings highlight both the potential and the methodological gaps in current research.

Research highlights the potential of robotic systems to individualize therapy through machine learning algorithms and sensor technologies that enable personalized rehabilitation programs[10,29]. Evidence indicates that early and intensive intervention improves outcomes, although benefits may be less pronounced in patients with severe impairments[13,31]. Authors also emphasize the importance of patient-centered approaches and multidisciplinary involvement, extending rehabilitation beyond physiological recovery to social and psychological adaptation[9,15]. Clinical trials further support the use of soft exoskeletons and task-specific robotic protocols for restoring gait and coordination after stroke[19,32].

In addition to motor improvements, robotic systems enhance motivation and therapy adherence through interactive feedback and gamified elements, while AI-supported platforms adjust assistance levels in real time based on biomechanical data[7,14,15,29].

Nevertheless, significant limitations persist, including the lack of standardized assessment criteria, limited longitudinal data, high equipment costs, and unequal access to advanced technologies[12,14,16,30]. Consequently, further large-scale and multicenter studies are required to strengthen the evidence base and support the development of standardized rehabilitation protocols.

MATERIALS AND METHODS

Study design

The study was designed as a randomized controlled trial aimed at evaluating the effectiveness of combining traditional physiotherapy with robotic technologies in post-stroke rehabilitation. Participants were randomly assigned to the control and experimental groups using a computer-generated randomization sequence to minimize selection bias.

The assessors who performed functional evaluations using the Fugl–Meyer Assessment (FMA), the Timed Up and Go (TUG) test, and the Six-Minute Walk Test (6MWT) were blinded to group allocation to reduce observer bias.

The study was conducted at the Department of Rehabilitation and Restorative Treatment of Kyiv City Clinical Hospital No. 4, Kyiv, Ukraine. The study was carried out from January 6 to March 16, 2025. The active rehabilitation intervention lasted eight weeks (January 6 to March 2, 2025), followed by a two-week period (March 3 to March 16, 2025) dedicated to data processing and statistical analysis.

Population and sample

The study involved 62 patients aged 42 to 68 years (mean age 59 ± 3.15 years) undergoing rehabilitation after ischemic stroke. There were 25 (40.3%) women and 37 (59.7%) men.

The sample size was determined using an a priori power analysis performed in G*Power software (version 3.1.9.7; Heinrich Heine University Düsseldorf, Düsseldorf, Germany). The calculation was based on the primary outcome variable, the FMA score, selected as the principal measure of post-stroke motor recovery. A medium effect size (Cohen's d = 0.5) was assumed based on previous studies reporting moderate effects of robotic-assisted rehabilitation after stroke. With a power of 0.80 and a two-sided significance level of $\alpha = 0.05$, the minimum required sample size was 52 participants. To account for potential attrition, 62 patients were ultimately included. All participants were clinically stable at the time of inclusion.

The sample was randomly assigned to two equal groups: a control group (n = 31), which received conventional physiotherapy and individual sessions with an exercise instructor, and an experimental group (n = 31), which additionally received robot-assisted rehabilitation using lower-limb exoskeletons and upper-limb robotic simulators with sensory feedback.

Inclusion criteria were: confirmed diagnosis of ischemic stroke in the subacute or chronic recovery phase, motor impairment in at least one limb, clinical stability, and ability to perform moderate-intensity physical activity without acute complications. Exclusion criteria included severe cardiovascular, respiratory, or orthopedic comorbidities limiting safe participation in exercise; cognitive or psychiatric disorders affecting task performance; uncontrolled hypertension; recurrent acute stroke; or inability to provide informed consent.

Interventions and devices

The rehabilitation program lasted eight weeks and combined standard physiotherapeutic exercises aimed at restoring mobility, coordination, and muscle strength with two weekly sessions of robot-assisted therapy. All sessions were supervised by qualified physical therapists.

The control group performed conventional therapeutic exercises including active and passive range-of-motion activities for affected joints, gait and balance training, sit-to-stand and step-up exercises, resistance training for upper and lower limbs, and coordination tasks to improve functional mobility and muscle endurance.

The experimental group followed the same conventional program supplemented with robot-assisted sessions using the Lokomat® robotic gait trainer (Hocoma AG, Switzerland) for lower-limb rehabilitation and the Armeo® Power robotic arm trainer (Hocoma AG, Switzerland) for upper-limb rehabilitation. Both systems provide active-assisted movements with adjustable body-weight support and real-time sensory feedback, enabling repetitive, guided exercises under therapist supervision.

Conventional therapy sessions were conducted five times per week, lasting approximately 45–60 minutes each. The experimental group followed the same schedule and additionally received two weekly robot-assisted sessions of approximately 60 minutes. Therapy intensity, duration, and environmental conditions were standardized to ensure methodological comparability and patient safety.

Evaluation procedures

The effectiveness of the interventions was assessed using FMA, TUG, and 6MWT. Assessments were conducted at baseline, after 4 weeks, and at the end of the 8-week program to monitor functional changes over time.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics, version 26.0. Descriptive statistics were expressed as mean ± standard deviation (SD) and percentage change (Δ%). Data normality was assessed using the

Shapiro–Wilk test. As the variables did not meet normality assumptions, nonparametric tests were applied.

Within-group changes in FMA, TUG, and 6MWT scores between baseline, week 4, and week 8 were analyzed using the Wilcoxon signed-rank test. Intergroup differences were assessed using the Mann–Whitney U test. A p-value < 0.05 was considered statistically significant.

Additionally, 95% confidence intervals (CI) and effect size measures (Cohen's d) were calculated for key outcomes to enhance the robustness and interpretability of the results.

RESULTS

The collected data demonstrated that patients in the experimental group exhibited more pronounced progress in restoring motor functions compared with those who received traditional therapy. The difference was reflected not only in quantitative indicators but also in the subjective evaluations of participants: patients reported decreased stiffness, greater confidence in movement, and a faster return to everyday activity.

The analysis of the FMA results revealed a steady improvement in both groups, with a more marked increase in the experimental group. At baseline, mean scores were nearly identical between groups (41.72 ± 4.15 in the control group and 41.69 ± 4.08 in the experimental group). After 4 weeks, the scores increased to 44.15 ± 3.92 and 46.82 ± 3.85, respectively, while at the end of the eighth week they reached 45.33 ± 4.01 and 48.35 ± 4.12 points. The total improvement was +3.61 points in the control group and +6.66 points in the experimental group, indicating faster and more effective motor function recovery among patients undergoing robotic-assisted rehabilitation (Table 1).

Table 1. Dynamics of FMA scale results in the control and experimental groups (mean ± SD

Stage of measurement	Control group (n=31)	Experimental group (n=31)	p-value	Effect size (ohen's)
Baseline	41.72 ± 4.15	41.69 ± 4.08	0.970	0.01
4th week	44.15 ± 3.92	46.82 ± 3.85	0.012*	0.68
8th week	45.33 ± 4.01	48.35 ± 4.12	0.005**	0.76

The results of the TUG test showed significant improvements in walking speed and postural stability, particularly in the experimental group. Baseline mean times were 18.46 ± 2.74 s and 18.44 ± 2.71 s, respectively. After 4 weeks, performance times improved to 16.87 ± 2.61 s (control) and 15.42 ± 2.57 s (experimental), and by week 8 they reached 16.12 ± 2.59 s and 14.29 ± 2.48 s. The overall improvement was −2.34 s in the control group and −4.15 s in the experimental group, reflecting greater gait efficiency and better coordination achieved through robotic training (Table 2).

Table 2. Dynamics of TUG test results in the control and experimental groups (mean ± SD)

Stage of measurement	Control group (n=31)	Experimental group (n=31)	p-value	Effect size (ohen’s)
Baseline	18.46 ± 2.74	18.44 ± 2.71	0.960	0.01
4th week	16.87 ± 2.61	15.42 ± 2.57	0.018*	0.55
8th week	16.12 ± 2.59	14.29 ± 2.48	0.004**	0.72

The 6MWT results also demonstrated a consistent upward trend in both groups, with significantly better dynamics in the experimental group. Initially, both groups showed nearly identical endurance levels (288.37 ± 26.9 m versus 288.41 ± 27.2 m). After 4 weeks, the mean distances increased to 302.54 ± 25.6 m and 318.02 ± 24.9 m, and after 8 weeks they reached 309.15 ± 25.1 m and 332.84 ± 23.8 m, respectively. The total gain was +20.78 m in the control group and +44.43 m in the experimental group, confirming improved endurance and aerobic capacity among patients who participated in robotic-assisted rehabilitation (Table 3).

Table 3. Dynamics of 6MWT results in the control and experimental groups (mean ± SD)

Stage of measurement	Control group (n=31)	Experimental group (n=31)	p-value	Effect size (ohen’s)
Baseline	288.37 ± 26.9	288.41 ± 27.2	0.990	0.00
4th week	302.54 ± 25.6	318.02 ± 24.9	0.019	0.61
8th week	309.15 ± 25.1	332.84 ± 23.8	p< 0.001	0.97

The integrated comparison of all parameters (Table 1) confirmed the superiority of the robotic-assisted program. The mean FMA score increased by 6.63 points, the TUG test time decreased by 4.17 seconds, and the 6MWT distance increased by 44.47 meters (Table 4).

Table 4. Comparison of baseline values in the control group and final rehabilitation outcomes in the experimental group

Indicator	Control group (traditional therapy)	Experimental group (robotic therapy)	Difference ( )
FMA (points)	41.72	48.35	+6.63
TUG (seconds)	18.46	14.29	-4.17
6MWT (meters)	288.37	332.84	+44.47

As shown in (**Table 1**), patients in the experimental group demonstrated clear advantages across all three key indicators. The FMA score increased by 6.63 points (41.72 → 48.35), the TUG test time decreased by 4.17 seconds (18.46 → 14.29), and the 6MWT distance increased by 44.47 meters (288.37 → 332.84). These findings confirm the effectiveness of robotic systems in accelerating functional recovery and enhancing the quality of life of patients. The differences between groups are also clearly visualized in (**Figure 1**).

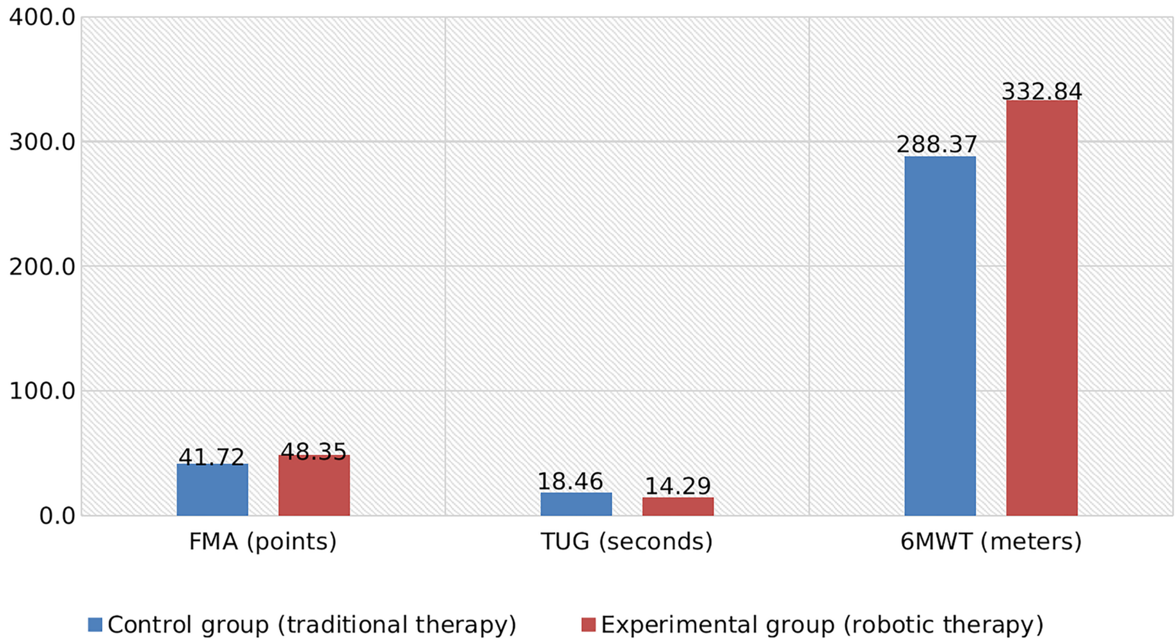

Figure 1.Comparison of average rehabilitation results of patients in the control and experimental groups

The analysis of the obtained results indicates that robotic-assisted therapy led to faster and more stable recovery of motor functions, coordination, and endurance. Improvements were observed across all three assessment scales, with statistically significant differences ($p < 0.05$) in favor of the experimental group. The obtained data are consistent with global research, which emphasizes that robotic devices enhance the intensity and precision of movements and contribute to the activation of neuroplastic mechanisms underlying functional recovery.

These results justify the inclusion of robotic systems in comprehensive rehabilitation protocols as a complementary component rather than a replacement for traditional therapy. Combining classical physiotherapy with robotic simulators allows for a higher level of movement repeatability, precision, and motivation, resulting in more sustainable recovery. Expanding access to robotic technologies beyond specialized centers to regional hospitals is also essential, particularly through the development of mobile and home-based rehabilitation systems. This approach could ensure continuity of treatment, reduce the burden on healthcare professionals, and extend rehabilitation services to patients in remote areas.

Further development of artificial intelligence and sensor technologies will allow robotic devices to adapt training intensity automatically according to the patient's condition, physical capacity, and fatigue level. This technological personalization can reduce the risk of overload, increase engagement, and make rehabilitation more effective. The creation of unified electronic registries to monitor rehabilitation outcomes will also enable the collection of clinical data necessary to evaluate the long-term effectiveness of robotic technologies and improve evidence-based guidelines.

In general, the combination of robotic and traditional rehabilitation ensures higher recovery efficiency, accelerates the restoration of motor skills, and improves patients' independence and quality of life. The results of this study confirm that the integration of robotics into rehabilitation practice represents a promising and effective direction for the development of modern restorative medicine.

DISCUSSION

The results of the pilot study in Ukraine confirmed the effectiveness of integrating robotic systems into the rehabilitation of patients after stroke. The significant increase in performance in the group treated with exoskeletons and robotic simulators is consistent with the findings of other authors who noted improvements in motor function and shorter recovery times due to the use of innovative technologies(4,26). In our study, patients demonstrated increased endurance, speed, and coordination, which supports the hypothesis that a combination of traditional and robotic therapies is feasible.

These findings are consistent with international clinical evidence indicating that robotic-assisted rehabilitation significantly enhances motor recovery and functional independence after stroke. Systematic reviews and meta-analyses highlight that robotic systems—particularly lower-limb exoskeletons and upper-limb robotic arms—promote improved gait performance, balance, and coordination when compared with conventional physiotherapy alone(3,4,6,26). The integration of robotics into multimodal rehabilitation programs also facilitates personalized therapy through adaptive control, feedback mechanisms, and repetition intensity, all of which accelerate neural reorganization and functional outcomes.

At the same time, the results also reflect the contradictions that other scientific studies have documented. In particular, a number of meta-analyses indicate significant variability in effectiveness depending on the severity of the condition, the time of the intervention, and the level of active patient participation(11,13). In our sample, patients with moderate impairment showed more pronounced progress, while in cases of more severe impairment, the positive dynamics of recovery was less noticeable. This is in line with the data of Wang et al.(25), who emphasize that early intervention and sufficient intensity of therapy are key success factors.

Special attention should be paid to the issue of long-term effectiveness. Most studies, like ours, demonstrate short-term improvements in functional performance, but there is a lack of data on the sustainability of these changes in the long term(1,2). This leads to the conclusion that additional longitudinal studies with extended follow-up periods are needed.

The synthesis of current evidence also indicates several strengths and limitations of robotic rehabilitation. Its main advantages include high training intensity, repeatability of movement, precise control, and enhanced motivation through real-time biofeedback. These features explain the accelerated improvement in motor skills and endurance observed in the experimental group. However, persistent challenges remain: heterogeneity of devices and study protocols, dependency on early-stage intervention, and patient engagement significantly affect outcomes. Moreover, long-term superiority over conventional therapy is not consistently demonstrated due to short follow-up periods and small sample sizes in many trials[11,13,31,34].

It is also worth considering the discussion about the practical availability of robotic technologies. Although their effectiveness is undeniable, a number of authors emphasize the high cost of equipment and the need for specially trained personnel[9,14]. Our study confirms this thesis, as the implementation of the systems was possible only through cooperation with multidisciplinary clinics. This finding corresponds with global analyses that identify economic and infrastructural barriers as key limiting factors for the broader integration of robotics in routine rehabilitation settings, particularly in developing healthcare systems.

Thus, the results of our own experiment correlate with international trends and emphasize both the strengths of robotic systems – increased motor skills, endurance, and motivation – and the limitations associated with the severity of patients' conditions, differences in protocols, and financial barriers. Overall, these outcomes reinforce the view that robotic technology should be regarded as a complementary enhancement to traditional rehabilitation rather than a replacement. The common conclusion of most scientific papers, which is confirmed by our study, is that robotics should be considered an important complement to classical therapy, not a complete replacement. Further research should focus on standardizing protocols, evaluating long-term outcomes, and finding ways to make innovative technologies more accessible to patients.

CONCLUSIONS

The findings confirm that robotic systems combined with traditional physiotherapy significantly enhance motor function, endurance, and movement speed in post-stroke rehabilitation. Greater benefits were observed in patients in the subacute phase and with moderate impairment, whereas individuals with severe deficits showed slower progress, highlighting the need for personalized protocols supported by adaptive algorithms.

The originality of this study lies in the implementation of robot-assisted rehabilitation under real clinical conditions in Ukraine, providing practical evidence from a healthcare system facing infrastructural and economic constraints. However, the relatively small sample size and short follow-up period limit the generalizability and long-term interpretation of the results.

The practical implications suggest that robotic rehabilitation may be extended beyond specialized centers to regional facilities, particularly with the development of mobile and remotely monitored systems. Future research should prioritize multicenter trials with long-term follow-up, evaluation of optimal treatment intensity and timing, economic feasibility analyses, and further integration of robotics with artificial intelligence, virtual environments, and sensor technologies to establish standardized and evidence-based rehabilitation protocols.

ETHICAL CONSIDERATIONS

The study was conducted in accordance with the principles of the Declaration of Helsinki and national ethical guidelines for clinical research involving human participants. The study protocol was approved by the Commission on Bioethical Expertise and Ethics of Scientific Research of Bogomolets National Medical University, Kyiv, Ukraine (approval No. 148/24, dated December 19, 2024). All participants provided written informed consent prior to inclusion in the study, and confidentiality of personal data was strictly maintained throughout the research.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

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