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THE SIGNIFICANCE OF ROBOT-ASSISTED THERAPY ON THE RECOVERY OF MOTOR FUNCTION IN PATIENTS AFTER ISCHEMIC STROKE

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Ischemic stroke (ISU) represents an acute, focal neurological deficit due to compromised blood flow to a specific region of the brain. The goal of rehabilitation is to improve mobility, balance, coordination and independence in daily activities, through individually tailored treatments. The use of medical rehabilitation devices enabled the early mobilization of patients with pronounced motor deficits, through the control and support of the movements of weakened muscles.
The objective was to compare the effectiveness of robot-assisted therapy on the recovery of motor function in patients after IMU compared to conventional rehabilitation.
A prospective comparative study was conducted at the Clinic for Physical Medicine and Rehabilitation of the University Hospital Niš during 2025, in 40 patients after IMU, both sexes, average age 66.82±9.09 years. The subjects were divided into control and experimental groups. The control group consisted of subjects undergoing conventional rehabilitation, whose medical histories were retrospectively investigated, and the experimental group of subjects who also underwent robot-assisted treatment. The motor function of the extremities was assessed using the Fugl-Meyer scale, at admission and discharge. The average duration of rehabilitation was 16.15±4.3 days, with no statistically significant difference between the groups (t= 0.82< t (40 and 0.01), p>0.01). The average value of the improvement of the motor function of the upper limbs is 4.35±1.93 for the control group, 11.35±4.05 for the experimental group. The comparison revealed the existence of a statistically significant difference in favor of the experimental group (t= 6.97> t (40 and 0.01), p<0.01). The average value of improvement in the motor function of the lower extremities was 2.55±1.28 for the control group, 6.8±2.04 for the experimental group. The comparison revealed the existence of a statistically significant difference in favor of the experimental group (t= 7.87> t (40 and 0.01), p<0.01).
The results indicate the existence of a statistically significant difference in the effects of robot-assisted treatment compared to the conventional approach.

Key words: ischemic stroke, conventional rehabilitation, robot-assisted treatment

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ZNAČAJ ROBOTSKI ASISTIRANE TERAPIJE NA OPORAVAK MOTORIČKE FUNKCIJE KOD PACIJENATA NAKON ISHEMIJSKOG MOŽDANOG UDARA

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Ishemijski moždani udar (IMU) predstavlja akutni, fokalni neurološki deficit zbog kompromitovanog dotoka krvi u određenu regiju mozga. Cilj rehabilitacije je poboljšanje pokretljivosti, ravnoteže, koordinacije i samostalnosti u svakodnevnim aktivnostima, kroz individualno prilagođene tretmane. Korišćenje medicinskih rehabilitacionih uređaja omogućilo je ranu mobilizaciju pacijenata sa izraženim motoričkim deficitom, kroz kontrolu i podršku pokreta oslabljenih mišića.
Cilj je bio upoređivanje efikasnosti robotski asistirane terapije na oporavak motoričke funkcije kod pacijenata nakon IMU u odnosu na konvencionalnu rehabilitaciju.
Rađena je prospektivna komparativna studija, na Klinici za fizikalnu medicinu i rehabilitaciju UKC Niš tokom 2025. godine, kod 40 pacijenata nakon IMU, oba pola, prosečne starosti 66,82±9,09 godina. Ispitanici su podeljeni na kontrolnu i eksperimentalnu grupu. Kontrolna su činili ispitanici podvrgnuti konvencionalnoj rehabilitaciji, čije su Istorije bolesti retrospektivno istraživane, a eksperimentalnu ispitanici podvrgnuti i robotski asistiranom tretmanu. Procenjivana je motorička funkcija ekstremiteta pomoću Fugl-Meyer skale, na prijemu i otpustu.
Prosečno trajanje rehabilitacije iznosilo je 16,15±4,3 dana, bez statistički značajne razlike između grupa (t= 0,82< t (40 i 0,01), p>0.01). Prosečna vrednost poboljšanja motoričke funkcije gornjih ekstremiteta je 4,35±1,93 za kontrolnu, 11,35±4,05 za eksperimentalnu grupu. Poređenjem je utvrđeno postojanje statistički značajne razlike u korist eksperimentalne grupe (t= 6,97> t (40 i 0,01), p<0.01). Prosečna vrednost poboljšanja motoričke funkcije donjih ekstremiteta iznosila je 2,55±1,28 za kontrolnu, 6,8±2,04 za eksperimentalnu grupu. Poređenjem je utvrđeno postojanje statistički značajne razlike u korist eksperimentalne grupe (t= 7,87> t (40 i 0,01), p<0.01).
Rezultati ukazuju na postojanje statistički značajne razlike u efektima robotski asistiranog tretmana u odnosu na konvencionalni pristup.

Ključne reči: ishemijski moždani udar, konvencionalna rehabilitacija, robotski asistiran tretman

INTRODUCTION

A stroke (cerebrovascular disease), according to the definition of the American Association for the Prevention and Treatment of Stroke, is a disease caused by the interruption of circulation to certain regions of the brain due to the occlusion or rupture of a blood vessel when brain tissue is damaged (1).

It represents a major, progressive global health problem and a significant socioeconomic burden as a leading cause of physical disability in adults and mortality in developed countries. According to the available data, the incidence of stroke varies in different countries and is between 100 and 300 new cases per 100,000 inhabitants annually, with an increase with age and an increase in the specific mortality rate, which doubles with each decade after the age of 55 (2). Stroke can be divided into two categories: hemorrhagic (20-25%) and ischemic stroke (75-80%), depending on the mechanism of occurrence (3).

Ischemic stroke (ISU) is defined as an acute, focal neurological deficit resulting from a below-critical level of reduced or completely interrupted blood flow to a certain region of the brain (4).

Despite the improvement of medical technology, the mechanism of origin and etiological nature of ischemic stroke in most patients remains unknown. The etiology of ischemic stroke is usually multifactorial and may include atherosclerotic changes in large blood vessels, cardioembolic sources, ischemia of small blood vessels, cerebral vasospasms, hypercoagulable conditions, etc. Risk factors for ischemic stroke are age, male gender, previous ischemic stroke or transient ischemic attack, arterial hypertension, diabetes, obesity, hyperlipidemia, unhealthy diet, smoking and insufficient physical activity (5). The clinical picture of an ischemic stroke occurs suddenly and depends on several factors, such as the localization and extent of the lesion, and may include motor disorders in the form of monoparesis, hemiparesis and hemiplegia, speech disorders, vision disorders, balance and coordination disorders, sensory deficits, cognitive and emotional disorders (6). The current gold standard for the diagnosis of ischemic stroke includes taking anamnestic data, clinical assessment of stroke severity based on the National Institutes of Health Stroke Scale (NIHSS), and imaging of the brain and neurovascular structures. The NIHSS is a widely applicable scale, which includes assessment of alertness, eye movements, visual field preservation, facial movements, limb muscle strength, sensation, coordination, and speech (7). Imaging techniques used in the diagnosis of ischemic stroke include noncontrast computed tomography (NCCT), as a fast, widely available and effective method, CT angiography and perfusion and magnetic resonance imaging (MRI) (Figure 1) (8).

Figure 1. CT of the endocranium. Chronic ischemic lesion posterior frontal right (source: Archives of the Radiology Center of the University Clinical Center Niš)

Acute treatment of ischemic stroke aims to reperfuse the endangered brain tissue as quickly as possible to prevent complications and secondary brain damage. It includes intravenous treatment with alteplase, with the aim of thrombolysis, alone or in combination with mechanical thrombectomy, depending on the size of the occluded blood vessel, as well as the application of antiplatelet therapy to reduce the risk of recurrent stroke (9).

Despite progress in acute patient care, a large number remain with permanent impairments, which is why rehabilitation is an important segment for their functional recovery (10). The functional recovery of patients after ischemic stroke is based on an ability of the central nervous system called neuroplasticity. Neuroplasticity represents the ability of the nervous system to change its activity in response to various stimuli through the reorganization of structures, functions and connections after damage, such as stroke (11). According to the National Guide to Good Clinical Practice, rehabilitation should be started as early as possible, as an essential element in the successful treatment of patients after ischemic stroke (12). The goal of rehabilitation is to preserve and improve the mobility of the affected limbs, prevent contractures and pressure ulcers, improve balance and coordination, and increase independence in performing daily activities. In the acute phase of the disease, early rehabilitation includes adequate positioning of patients in order to prevent the occurrence of decubitus wounds and contractures, passive and assisted range of motion exercises, breathing exercises and early mobilization of patients in the form of positioning in a sitting and standing position under the supervision of an expert. In the later stages of the disease, there are active exercises with the aim of strengthening muscles, improving balance and coordination, walking exercises on flat and then uneven ground, functional exercises of the upper extremities with the aim of enabling them to perform daily activities and fitness training. Kinesitherapy included breathing exercises and general conditioning, active and actively assisted exercises, gait, balance and coordination exercises, while occupational therapy included functional occupational therapy, balance and coordination exercises, activities of daily living and self-care. Kinesitherapy, as a part of physical therapy, represents one of the most important aspects of medical rehabilitation that deals with the application of systematized movements of certain parts or the whole body in the form of exercises with the aim of preserving, establishing, developing or replacing the functions of the locomotor system, organs and systems that are functionally related to mobility (13). Occupational therapy refers to activities related to self-care and improvement of fine motor coordination of muscles and joints. Occupational therapy develops the ability to use objects for everyday use (14). Rehabilitation program is individual for each patient, and the intensity and types of exercises depend on the degree of neurological deficit, comorbidity and motivation of the patient (15).

Through the integration of biomechanical principles and motorized assistance, the progress of modern rehabilitation technologies, and the need for individualized and more effective therapeutic interventions, medical rehabilitation devices were formed in recent decades that enabled the early mobilization of patients with severe motor deficits (16). Robot-assisted therapy that has found practical application in the rehabilitation of patients after an ischemic stroke is the use of the THERA-Trainer Tigo device. The Tigo device is a rehabilitation ergometer designed to move in a cycling pattern, with a motor that supports the patient's movement, enabling passive, assisted or active activity. Application of the Tigo device improves muscle strength, range of motion, circulation and neuromuscular activation. Thanks to robot-assisted devices, precise therapeutic interventions are possible, which provide control of limb movements and support of movements of weakened muscles (17).

AIM

The aim of this research was to compare the effectiveness of robot-assisted therapy in the recovery of motor function in patients after ischemic stroke compared to the conventional approach in rehabilitation.

MATERIAL AND METHODS

During this research, a prospective comparative study with a historical control group was conducted. The research was conducted at the Clinic for Physical Medicine and Rehabilitation of the University Hospital Nis in the period from January to December 2025, in 40 patients after ischemic stroke, both sexes, average age 66.82±9.09 years. Subjects included in the study were patients with a first ischemic stroke verified on CT or MRI, with a clinical picture of mild to moderate stroke and present right or left hemiparesis, with cognitive abilities to adequately understand the expected instructions. Subjects with a history of previous stroke, behavioral or cognitive disorders, signs of a pronounced degree of spasticity, with the occurrence of hospital infections, in which the achieved results were not followed up to the end, were excluded from the study. The research was started with 44 respondents, of which 4 respondents were excluded from the study.

The respondents were divided into two equal groups, control and experimental, with 20 respondents each. The distribution of respondents was made depending on the time period in which the rehabilitation was carried out. The subjects were patients who were admitted to the Clinic for Physical Medicine and Rehabilitation, one month after a mild to moderate ischemic stroke with impaired motor function. Patients are subjected to individually designed rehabilitation program according to the severity of the clinical picture and the degree of mobility limitation. The control group was made up of subjects whose medical histories were retrospectively investigated, and who were subjected to conventional rehabilitation that included occupational and kinesitherapy with the help of a physiotherapist, lasting three weeks.

In the experimental group, in addition to conventional rehabilitation, robot-assisted therapy using the THERA-Trainer Tigo device was included, for three weeks, five times a week, for half an hour. The THERA-Trainer Tigo device was used to improve the motor strenght of patients through controlled, repeatable and measurable execution of rotation of pedals or handles actively, assistively or passively depending on the individually adjusted motor power based on continuous and objective monitoring of parameters (18).

The parameters that were measured and analyzed in the patients included the assessment of motor function of the upper and lower extremities, sensitivity, balance in sitting and upright positions, range of motion and pain in the joints using Fugl-Meyer Assessment upper extremity (FMA-UE) and Fugl-Meyer Assessment lower extremity (FMA-LE). The FMA is a standardized clinical scale for reliable assessment of motor recovery after stroke and monitoring the course of rehabilitation. It covers five domains: motor function, sensation, balance, joint range of motion, and joint pain. Motor function is assessed through 50 items, of which 33 refer to the upper extremity, and 17 to the lower extremity. Each item is scored on a three-point scale (0–2), with a higher score indicating better function. The total maximum score is 226 points, of which a total of 100 points refers to motor function, 66 for the upper extremities and 34 for the lower extremities (19). All parameters were measured twice in total, once on admission, one month after the ischemic stroke, while the repeated measurement was performed at the end of the rehabilitation at the time of the patients' discharge. The measurement was performed by the same expert in adequate conditions.

STATISTICAL DATA PROCESSING

Data were statistically classified and processed using standard statistical tests (structure index, arithmetic mean, standard deviation, Student's t test of arithmetic means for two small dependent samples, Student's t test of arithmetic means for two small independent samples, Fisher's exact test).

RESULTS

The total number of respondents in the current research was 40. Of the total number of respondents, there were 32 men and 8 women (80% men, 20% women). The average age of the total population was 66.82±9.09 years. In the control group there were 5 women and 15 men, with an average age of 68.05±9.63 years, while in the experimental group there were 3 women and 17 men, with an average age of 65.6±8.29 years. After statistical data processing, it was determined that there was no statistically significant difference in the average age of the subjects between the control and experimental groups (Student's t test t= 0.27< t (40 and 0.01), p>0.01) (Table 1). There was no statistically significant difference in the gender of the subjects between the control and experimental groups (Fisher's exact test p=0,695, p>0.05) (Table 1).

Table 1. Patients' characteristics

Patients' characteristics	Control group	Experimental group	p	Total
No of patients	20	20	NS	40
Mean age years ±SD	68.05±9.63	65.6±8.29	NS	66.82±9.09
Gender male (No of patients)	15	17	NS	32
Gender female (No of patients)	5	3	NS	8

Footnote: Continuous variables are given as means (SD) and categorical variables as absolute number. Student's t test for small independent samples; Fisher's exact test

The number of days in the hospital in the control group was on average 15.6±4.34 days, while in the experimental group the average value was 16.7±4.2 days. The average value of rehabilitation duration for the total number of respondents was 16.15±4.3 days. There was no statistically significant difference in the average duration of rehabilitation in the control and experimental groups (Student's t test t= 0.82< t (40 and 0.01), p>0.01)(Table 2).

Table 2. Average duration of rehabilitation

	Control group	Experimental group	Total	t	p
Average duration of rehabilitation (days±SD)	15.6±4.34	16.7±4.2	16.15±4.3	0.82	>0.01

Footnote: Student's t test for small independent samples; p>0.01
*NS for all parameters

Using Fugl-Meyer Assessment upper extremity scale the average value of the motor function of the upper extremities on admission in the control group was 40±14.74, while in the experimental group this value was 38.7±11.27. Statistically significant difference in the motor function of the subjects in the control and experimental groups at the reception was not found (Student's t test t= 0.31< t (40 and

0.01), p>0.01). After individually adapted rehabilitation program, the average values of the motor function of the upper extremities were 44.35±13.78 for the control group and 50.05±12.14 for the experimental group. At discharge, there was significant improvement in motor function of upper extremities in experimental and control group compared to initial findings (p<0.01) (Table 3). The average value of the improvement of the motor function of the upper limbs of the subjects of the control group was 4.35±1.93, while in the experimental group this value was 11.35±4.05. By comparing the average improvement values between the groups, it was determined that there was a statistically significant difference in favor of the experimental group (Student's t test t= 6.97> t (40 and 0.01), p<0.01)(Table 4).

Table 3. Average values of the motor function of the upper and lower extremities using Fugl-Meyer scale

	Control group			Experimental group		
	Before therapy	After therapy	P	Before therapy	After therapy	P
Average values of UE motor function	40±14.74	44.35±13.78	p<0.01	38.7±11.27	50.05±12.14	p<0.01
Average values of LE motor function	23.75±5.91	26.3±5.16	p<0.01	20.9±4.85	27.9±4.24	p<0.01

Footnote: Data are given as mean value (SD), Student's t test for small dependent samples

Table 4. Average values of the upper and lower extremities motor function improvement at discharge using Fugl-Meyer scale

	Control group	Experimental group	p
Average values of the upper extremities motor function improvement	4.35±1.93	11.35±4.05	p<0.01
Average values of the lower extremities motor function improvement	2.55±1.28	6.8±2.04	p<0.01

Footnote: Data are given as mean value (SD), Student's t test for small independent samples

Using Fugl-Meyer Assessment lower extremity scale the average value of the motor function of the lower extremities on admission in the control group was 23.75±5.91, while in the experimental group this value was 20.9±4.85. Statistically significant difference in the motor function of the subjects in the control and experimental groups on admission was not noticed (Student's t test t= 1.68< t (40 and 0.01), p>0.01). After individually adapted rehabilitation program, the average values of the motor function of the lower extremities were 26.3±5.16 for the control group and 27.9±4.24 for the experimental group. There was statistically significant difference in the motor function of the subjects in the control and experimental groups at the discharge compared to initial findings (Student's t test t= 0.39 < t (40 and 0.01), p<0.01)(Table 3). The average value of the improvement of the motor function of the lower extremities of the subjects of the control group was 2.55±1.28, while in the experimental group this value was 6.8±2.04. By comparing the average improvement values between the groups, a statistically significant difference was found in favor of the experimental group (Student's t test t= 7.87> t (40 and 0.01), p<0.01)(Table 4).

DISCUSSION

There is a large number of available research that indicates the prevalence of stroke in the elderly population and its impact on the socioeconomic status, which is why the goal of modern research is the most efficient functional recovery in order to train patients for self-care and daily functioning. With the progress of modern rehabilitation technologies, medical rehabilitation devices have been continuously formed in recent decades. At the beginning of this century, research appeared, the results of which indicated that robot-assisted rehabilitation would deserve great recognition for its significant impact on the effectiveness of rehabilitation (20). Currently, their effectiveness is recognized by clinicians and they are widely used in clinical rehabilitation practice. While the first devices were simple and with limited application in rehabilitation, today's devices, through their modern designs, allow active physical and cognitive participation of patients (21). The "Lokomat" robot is a leading robotic device for gait rehabilitation in different groups of patients, especially those after a stroke. There are numerous studies whose results indicate the effectiveness of its application in relation to conventional medicine (22). Also, there are studies that indicate that R-BOT-PRO, a medical device that enables individual movements of the lower extremities by adjusting the standing angle, has found effective application in the rehabilitation of patients after a stroke by focusing on muscle strength and balance (23). According to the available data, about three quarters of patients after a stroke show certain cognitive deficits, which can significantly jeopardize the patients' functional recovery (24). There are results of several studies that indicate that motor and cognitive functions after a stroke can be improved through virtual reality technology, which can be a powerful tool for motivating patients to actively participate in different types of treatment (25).

The results of the current research indicate that there are statistically significant differences in the effects of robot-assisted treatment compared to the conventional approach to rehabilitation. Based on the obtained results, robot-assisted treatment represents an important rehabilitation method, which provides the possibility of adequate functional recovery in patients after ischemic stroke. After comparing the obtained results with numerous available data, it can be concluded that the effectiveness of robot-assisted treatment is equal to or better than conventional rehabilitation treatments (26). Robotic medical devices provide the opportunity for repetitive and intensive training in patients with pronounced deficits, reduce the need for physiotherapists, which has a long-term effect on reducing the costs of rehabilitation treatments, and encourage patient motivation through interactive programs (27). Despite the current development of similar rehabilitation technologies, there is significantly less research available compared to conventional treatment. For a more precise assessment of the effectiveness of robotically assisted treatment in patients after ischemic stroke, it is necessary to conduct a larger number of studies in which the monitoring takes place on a larger sample, in a longer time interval.

The currently conducted research has its shortcomings, namely the limited number of subjects included in the study and the application of conventional treatment together with robot-assisted treatment in subjects of the experimental group, which cannot completely rule out the role of conventional rehabilitation in the recovery of patients after ischemic stroke.

CONCLUSION

Based on the results obtained during this prospective comparative study, it can be concluded that robot-assisted treatment is a significant additional method in the rehabilitation of patients after ischemic stroke. The results indicate the existence of a statistically significant difference in the effects of robot-assisted treatment compared to the conventional rehabilitation approach, which can be explained by adequate individual interventions, with early mobilization of patients with difficulty in mobility through control and support of movements of weakened muscles. The obtained results represent a promising indicator for the continuation of the practical application of existing robotic assisted treatment and the continuation of further research into robotic devices in order to replace or support existing methods.

REFERENCES

1. Sacco RL, Kasner SE, Broderick JP, Caplan LR, Connors JJ, Culebras A, et al. An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2013;44:2064-2089.

2. Saini V, Guada L, Yavagal DR. Global Epidemiology of Stroke and Access to Acute Ischemic Stroke Interventions. Neurology Journals. 2021; 97(20):6-16.

3. Chung CP. Types of Stroke and Their Differential Diagnosis. Primer on Cerebrovascular Diseases (Second Edition). 2017: 372-376.

4. Feske SK. Ischemic Stroke. The American Journal of Medicine 2021; 134(12):1457-1464.

5. Radu RA, Terecoasa EO, Bajenaru OA, Tiu C. Etiologic classification of ischemic stroke: Where do we stand? Clinical Neurology and Neurosurgery. 2017; 159: 93-106.

6. Olmosovna MG, Atabayevich KA, Mirkhamzayevna MM. Ischemic stroke symptoms and treatment. Western European Journal of Medicine and Medical Science. 2024; 2(7):67-72.

7. Kwah LK, Diong J. National Institutes of health stroke scale (NIHSS). Journal of physiotherapy. 2014;60(1):61.

8. Patil S, Rossi R, Jabrah D, Doyle K. Detection, diagnosis and treatment of acute ischemic stroke: current and future perspectives. Frontiers in medical technology. 2022; 4:748949.

9. Mosconi MG, Paciaroni M. Treatments in Ischemic Stroke: Current and Future. Eur Neurol. 2022; 85(5): 349-366.

10. Powers WJ, Rabinstein AA, Ackerson t, Adeoye OM, Bambakidis NC, Becker K, et al. Guidelines for early menagment of patient with acute ishemic stroke: 2019 update to the 2018 guidelines for early menagment of patient with acute ishemic stroke: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2019; 50(12):e344-e418.

11. Cabral DF, Fried P, Koch S, Rice J, Rundek T, Pascual-Leone A, et al. Efficacy of mechanisms of neuroplasticity after a stroke. Restorative neurology and neuroscience. 2022; 40(2):73-84.

12. Ischemic stroke. National Guide to Good Clinical Practice. Ministry of Health in 2011.

13. Vasiyarova NM. The role of kinesiotherapy in rehabilitation of post-stroke patients. Russian Military Medical Academy Reports. 2020; 39(2S):63-64.

14. Garcia-Perez P, Rodriguez-Martinez MC, Lara JP, Cruz-Cosme C. Early occupational therapy intervention in the hospital discharge after stroke. International Journal of Environmental Research and Public Health. 2021; 18(24):12877.

15. Kartashev VP, Makhov AS, Karpova NV, Komarov MN. Physical rehabilitation of patients after ischemic stroke. Biomedical and Pharmacology Journal 2020; 13(4): 1947-1953.

16. Calabro RS, Sorrentino G, Cassio A, Mazzoli D, Andrenelli E, Bizzarini E, et al. Robotic-assisted gait rehabilitation following stroke: A systematic review of current guidelines and practical clinical recommendationsobot-assisted therapy in stroke rehabilitation. European Journal of Physical and Rehabilitation Medicine 2021 June;57(3):460-71.

17. Cespedes N, Irfan B Senft E, Cifuentes CA, Gutierrez LF, Rincon-Roncancio M, et al. A socially assistive robot for long-term cardiac rehabilitation in the real world. Front. Neurorobotics. 2021;15:633248.

18. Bartík P, Vostry M, Hudakova Z, Šagat P, Lesnakova A, Dukat A. The effect of early applied robot-assisted physiotherapy on Functional Independence Measure score in post-myocardial infarction patients. Healthcare. 2022; 10(5):937.

19. Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient: A method for evaluation of physical performance. Scand J Rehabil Med. 1975;7:13-31.

20. Rizzo A, Kim GJ. A SWOT analysis of the field of virtual reality rehabilitation and therapy. Presence: Teleoperators and Virtual Environments. 2005;14(2):119-146.

21. Aprile I, Guardati G, Cipollini V, Papadopoulou D, Mastrorosa A, Castelli L, et al. Robotic rehabilitation: an opportunity to improve cognitive functions in subjects with stroke. An explorative study. Frontiers in Neurology. 2020;(11):588285.

22. Laszlo C, Munari D, Maggioni S, Knechtle D, Wolf P, De Bon D. Feasibility of an intelligent algorithm based on an assist-as-needed controller for a robot-aided gait trainer (lokomat) in neurological disorders: a longitudinal pilot study. Brain Sci. 2023;13(4):612.

23. Oh SY, Nam YG. Effect of Robotic Assisted Rehabilitation Treatment Using R-BOT on Cognitive and Physical Function of Stroke Patients: A Retrospective Pilot Study. J Korean Soc Phys Med. 2024;19(4):35-46.

24. Lesniak M, Bak T, Czepiel W, Seniow J, Czlonkowska A. Frequency and prognostic value of cognitive disorders in stroke patients. Dement Geriatr Cogn Disord. 2008;26:356-63.

25. Riener R, Dietz V, Ward N. Virtual reality for neurorehabilitation. Oxford textbook of neurorehabilitation. 2015;26:418-39.

26. Ranzani R, Lambercy O, Metzger JC, Califfi A, Regazzi S, Dinacci D, et al. Neurocognitive robot-assisted rehabilitation of hand function: a randomized control trial pn motor recovery in subacute stroke. Journal of neuroengineering and rehabilitation. 2022;17(1):115.

27. Lo K, Stephenson M, Lockwood C. The economic cost of rovotic rehabilitation for adult stroke patient: a systematic review protocol. JBI Evid Synth.2018;16(8):1593-8.