Neurological Sciences
https://doi.org/10.1007/s10072-023-06739-3

ORIGINAL ARTICLE

Is the robotic rehabilitation that is added to intensive body rehabilitation effective for maximization of upper extremity motor recovery following a stroke? A randomized controlled study

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Received: 15 October 2022 / Accepted: 6 March 2023

Abstract

Background Trunk stabilization, which is a factor that directly affects the performance of affected upper-limb movements in stroke patients, is of critical importance in the performance of selective motor control.

Aims This study aimed to investigate the effects on upper-limb motor function of the addition of robotic rehabilitation (RR) and conventional rehabilitation (CR) to intensive trunk rehabilitation (ITR).

Methods A total of 41 subacute stroke patients were randomly allocated to two groups: RR and CR. Both groups received the same ITR procedure. Following ITR, a robot-assisted rehabilitation program of 60 min, 5 days a week, for 6 weeks, was applied to the RR group, and an individualized upper-limb rehabilitation to the CR group. Assessments were made at baseline and after 6 weeks using the Trunk Impairment Scale (TIS), Fugl-Meyer Upper Extremity Motor Evaluation Scale (FMA-UE), and Wolf Motor Function Test (WMFT).

Results Improvements were obtained in the TIS, FMA-UE, and WMFT scores for both groups ($p < 0.001$), with no superiority detected between the groups ($p > 0.05$). The RR group scores were relatively high, but not to a statistically significant.

Conclusions When added to intensive trunk rehabilitation, the robot-assisted systems, which are recommended as a stand-alone therapy method, produced similar results to conventional therapies. This technology can be used as an alternative to conventional methods under appropriate conditions of clinical opportunity, access, time management, and staff limitations. However, when RR is combined with traditional interventions such as intensive trunk rehabilitation, it is essential to investigate if the real effect is due to the robotic rehabilitation or the accumulation of positive effects of excessive movement or force spread associated with trained muscles.

Registration This trial was retrospectively registered in the ClinicalTrials.gov with NCT05559385 registration number (25/09/2022).

Keywords Stroke · Intensive trunk rehabilitation · Robotic rehabilitation · Motor function · Conventional rehabilitation

Introduction

The World Health Organization defines stroke as a functional disorder that occurs without any reason other than a vascular cause, can last longer than 24 h, may result in death, and in which clinical findings are seen with the worsening of cerebral functions [1]. Stroke is the second leading cause of death worldwide, affecting all body structures and functions, from the musculoskeletal system to the cardiorespiratory system [2–4]. The most prominent of these effects is the loss of neuromuscular function, which seriously diminishes the patient's independence in daily activities [5].

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Techniques to improve the reduced selective motor control after stroke integrate motor learning components in the brain [6]. The Penumbra area is prone to structural and functional remodeling because reperfusion occurs in the proximal of the damaged area [7]. Studies have indicated that rehabilitation after infarction induces synaptogenesis, dendritic branching and growth, and long-range connections, thereby contributing to plasticity formation [8]. Failure to direct the plasticity process using rehabilitative techniques leads to the onset of the "misuse" phenomenon, which is difficult to undo and forget a wrong pattern and then establish the proper movement pattern [9]. Therefore, the rehabilitation process should be carefully planned and maintained.

Stroke rehabilitation programs must be initiated as soon as possible to regain lost functional skills as much as possible, and the first 6 months following the disease is essential for motor recovery [10]. In particular, impairment of upper extremity functions is more pronounced than for a lower limb after a stroke. Significantly few patients can fully recover upper extremity functions, and permanent motor losses are observed in most patients [11]. Excessive motions of the trunk and shoulder are evident during upper extremity actions such as reaching and grabbing [9]. Since trunk stabilization is a factor that directly affects reducing excessive shoulder movements and improving the performance of distal extremity movements, it is crucial in rehabilitation programs [12].

Alternative treatments such as virtual reality, constraint-induced movement therapy, mirror therapy, and robot-assisted devices are used in addition to conventional rehabilitation techniques to provide motor recovery and increase the patient's functionality [13–15]. The main principle of these therapy methods is the development of motor learning and the plasticity ability of the brain using repetitive and purposeful movements [13].

In recent years, robot-assisted rehabilitation has also been used as a treatment method and this contributes to developing neuroplasticity with targeted multi-repetitive activities [14, 15]. The treatment program is progressed gradually and controlled with this method, and partial or close to normal progression can be achieved in lost functional skills by utilizing the plasticity feature of the brain [10, 16]. The amount of gain related to robotic rehabilitation can be interpreted more consistently with the data obtained from the sensors on the device.

The aim of this study was to compare the effects on motor function of the upper extremity of robotic (RR) and conventional rehabilitation (CR) programs applied in addition to intensive trunk rehabilitation (ITR) following stroke and to investigate whether one program is superior to the other.

Material and methods

Study design and ethics

While calculating the sample size of this randomized controlled study, the alpha error was accepted as 5% and power as 80%. The study of Lee et al. was taken as a reference for calculating the effect size [17]. Given the possibility of missing data, it was determined that the required sample size for the study should be at least 41 participants.

The study was performed in line with the principles of the Declaration of Helsinki and all patients signed the written consent form before the program. The study was approved by the Marmara University Clinical Research Ethics Committee (protocol ID: 168; date: 06.09.2021).

Participants

The study inclusion criteria were defined as (1) age 40–85 years and had a single stroke episode in the last 6 months, (2) Mini-Mental State Assessment score > 20, (3) able to sit safely, (4) no neglect issue, and (5) Fugl-Meyer Upper Extremity Assessment score < 58. The exclusion criteria were defined as (1) having elbow and/or wrist spasticity (according to single muscle Modified Ashworth Scale Score > 2), (2) severe visual impairment, (3) participation in another rehabilitation program, and (4) subluxation or pain in the shoulder region.

Forty-one subacute stroke patients were divided into two groups of RR and CR using online randomization software (www.randomizer.org) (Fig. 1). The same physiotherapist conducted two face-to-face assessment sessions and all treatments. All the participants performed a standardized ITR program. Following the ITR, patients received the rehabilitation program of their assigned group.

Assessments

The primary outcome of the study is Fugl-Meyer Upper Extremity Asesessment and secondary outcomes are Wolf Motor Function Test and Trunk Impairment Scale.

Demographic data form

The researchers created a form to include information of age, gender, stroke onset date, lesion type, affected side, and dominant extremity.

Fugl-Meyer Upper Extremity Assessment

This disease-specific scale was created as an objective motor impairment scale to assess recovery in post-stroke hemiplegic patients [18]. It includes subsections that evaluate joint movements, coordination, and reflex activities related to the shoulder, elbow, forearm, wrist, and hand. The maximum score that can be obtained is 66, with a high score indicating good motor condition. The affected upper extremities are assessed with the subject in a seated position.

Wolf Motor Function Test

This test was created to evaluate the motor ability of the upper extremity [19]. The test consists of 17 items, 15 of which are related to the fields of functional skill and performance time and 2 to muscle strength [20]. The total score is used for the functional ability of the patients. The 2 items of muscle strength evaluation were not used in this study.

Trunk Impairment Scale

This scale evaluates static and dynamic sitting balance and trunk coordination with 17 items. The total score ranges from 0 to 23 points, with a higher score indicating better performance. The test–retest and inter-rater reliability coefficients of the scale have been shown to be 0.85–0.99 [21].

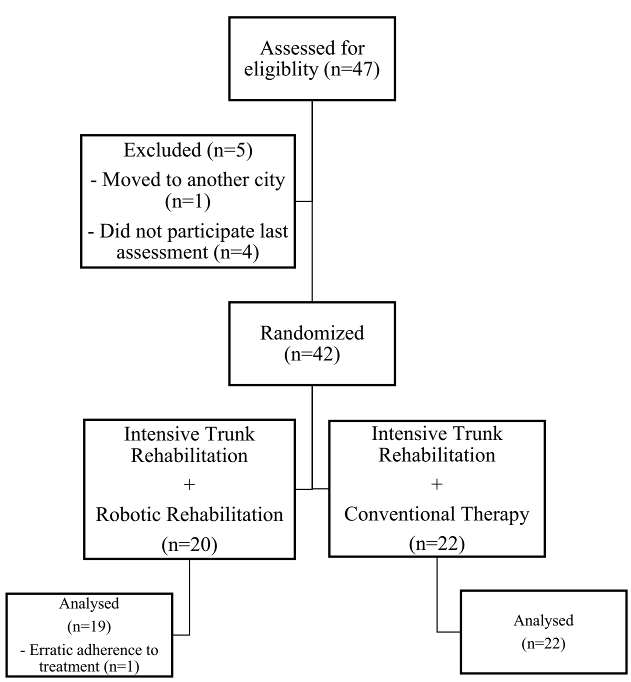

Fig. 1 The CONSORT flow diagram of the study

Study protocol

Intensive trunk rehabilitation protocol

The standardized ITR program was applied to both groups for 60 min a day, 5 days a week, for 6 weeks. During this period, an individualized rehabilitation program was applied to both groups in line with the needs of the patient in addition to trunk rehabilitation. Lower extremity rehabilitation was also included in this program. Exercises for the lower extremities were applied according to the individual needs of the patient. The ITR program included exercises of abdominal strengthening, controlled pelvic movements (anterior–posterior tilt, lateral lift, transverse rotation), bridging, trunk lateral flexion and rotation, reaching forward and sideways (by transferring weight), and push-ups with a Swiss Ball [22, 23].

Conventional rehabilitation group

CR applied after the ITR program consisted of an individualized rehabilitation program for the upper extremities according to the needs and functional status of the patients. These rehabilitation programs generally included activities for functional purposes (dressing, object manipulation, reaching, cup holding, range of motion, strengthening, weight-bearing, etc.). The treatment program was applied 5 days a week for 6 weeks, with the session duration limited to 60 min.

Robotic rehabilitation group

Following the ITR program, this group received (an exoskeletal rehabilitation intervention) robotic rehabilitation program for the upper extremity with ExoRehab X (Houston-Bionics, Inc.) device. ExoRehab X is a passive device that expects voluntary movement from the user on the shoulder abduction/adduction, elbow flexion/extension, forearm pronation/supination, wrist flexion/extension, and wrist radial/ulnar deviation. Patients initiate and maintain their movements during the exercise. The device supports the patient's active movement and motivates high movement repetition via gamification of tasks. The speed and resistance of the exercises can be adjusted, and exercises can be performed within the desired range of motion. The integrated sensors of the device provide feedback on patient development.

Before starting robotic rehabilitation, the patient was seated upright on the platform of the upper extremity robot with feet in contact with the ground and the upper extremity placed on the device. The games were projected onto a 43-inch television screen. The exercise program was planned to include upper extremity movements in all directions. The speed and resistance settings for the movements of the upper extremity in different planes were adjusted according to the individual characteristics of the patients. Particular attention was paid to adjusting the speed of the games to be at a level not to increase spasticity. The treatment was applied for the same duration as the conventional rehabilitation program to prevent the accumulation effect of the exercise ($60 \times 5 \times 6$ min/day/week).

Statistical analysis

The data were evaluated with the Statistical Package for the Social Sciences (SPSS v11) statistical program at 80% confidence interval and $p < 0.05$ significance. Demographic data were evaluated with frequency, mean, and standard deviation values from descriptive statistical methods. The normal distribution of the data was assessed with the Shapiro–Wilk test and histogram graphics. As the data were normally distributed, the Pearson's chi-square test, independent sample *t*-test, paired-sample *t*-test, and Pearson's correlation were used. While calculating the effect size of the variables, the amount of change (Δ) before and after treatment was taken as a reference. Cohen's reference ranges of 0.2 = low, 0.5 = medium, and 0.8 = high were acceptable for effect size [24]. The statistical analysis was performed by researchers. Due to the nature of this situation, blinding could not be performed.

Results

The data related to gender ($p = 0.537$), lesion type ($p = 0.846$), affected side ($p = 0.397$), age ($p = 0.258$), onset of stroke ($p = 0.002$), spasticity severity ($p = 0.899$), and mental status ($p = 0.130$) are shown in Table 1. The groups were similar in terms of demographic characteristics.

At baseline before starting the programs, the groups were similar in terms of Trunk Impairment Scale (TIS) scores ($p = 0.112$). The TIS scores increased significantly from 10.89 ± 6.44 to 17.68 ± 4.74 in the RR group ($p < 0.001$), and from 14.00 ± 5.63 to 18.00 ± 4.92 in the CR group ($p < 0.001$). There was a significant difference in favor of the RR in the Δ_{TIS} score ($p = 0.040$). The effect size was calculated as $d = 0.662$ (medium effect size according to Cohen) according to the Δ_{TIS} score. In this context, the improvement in the TIS score in the RR group was at a level that could be considered clinically significant.

There was no significant difference between the groups in respect of the baseline ($p = 0.553$) and 6-week ($p = 1.00$) results of Fugl-Meyer Upper Extremity Assessment (FMA-UE). The RR was not seen to have any advantage over the CR ($\Delta p = 0.456$). Cohen's effect size was calculated as $d = 0.242$ with the $\Delta_{FMA\text{-}UE}$. This rate did not indicate a clinically significant difference between the two treatment methods. The within-group comparisons determined that both treatment methods led to improvements in upper extremity motor gains compared to the initial evaluation ($p < 0.001$ for all).

No difference was determined between the two groups in respect of the Wolf Motor Function Test (WMFT) results evaluating the motor functions of the upper extremity ($p = 0.556$, $\Delta p = 0.328$). Both robotic rehabilitation ($p < 0.001$) and conventional treatment methods ($p < 0.001$) were determined to improve upper extremity motor functions. The effect size was calculated as $d = 0.312$ according to the Δ_{WMFT}. This ratio indicated that there was no clinically significant difference between the two treatment methods in respect of improving the WMFT score.

Table 1 Characteristics of the patients

Variables	Groups		*p*
	Robotic	Conventional	
Gender, *n* (%)			
Female	9 (47.40)	8 (36.40)	0.537
Male	10 (52.60)	14 (63.60)	
Type of lesion, *n* (%)			
Ischemic	16 (84.20)	19 (86.40)	0.846
Hemorrhagic	3 (15.80)	3 (13.60)	
Affected side, *n* (%)			
Right	7 (36.80)	11 (50.00)	0.397
Left	12 (63.20)	11 (50.00)	
Age (years)	60.21 ± 10.53	63.72 ± 9.08	0.258
Stroke onset (months)	4.00 ± 1.59	5.45 ± 1.05	0.002*
Modified Ashworth Scale (0–4)	1.68 ± 1.20	1.72 ± 0.94	0.899
Mini Mental State Examination (0–30)	23.15 ± 2.87	25.72 ± 6.71	0.130

*Statistically significant

No significant correlation was found between TIS scores and FMA-UE and WMFT scores of the groups (Tables 2 and 3).

Discussion

The primary purpose of this study was to compare the effects on upper extremity motor functions of robotic and conventional rehabilitation programs added to intensive trunk rehabilitation following stroke and to investigate whether they are superior to each other in terms of improving this parameter. Around this research question, we did not find not any superiority in favor of robotic rehabilitation or conventional rehabilitation in addition to intensive trunk rehabilitation on FMA-UE and WMFT. According to the correlation analysis results, there was no significant relationship between the TIS and the FMA-UE or WMFT scores in either the robotic rehabilitation or conventional groups. But, both treatments caused some improvements compared to the baseline. In addition, robotic rehabilitation provided greater gains on trunk impairment.

Table 2 Change of variables in the groups as a result of the rehabilitation protocols

Variables	Timeline	Groups		*p*	ES (*d*)
		Robotic	Conventional		
FMA-UE	Baseline	30.00 ± 11.67	32.81 ± 17.38	0.553	0.240
	6 weeks	46.68 ± 12.20	46.68 ± 16.45	1.00	
	$\Delta_{FMA\text{-}UE}$	16.68 ± 8.23	13.86 ± 14.41	0.456	
	p	< 0.001*	< 0.001*	-	
WMFT	Baseline	32.63 ± 15.00	38.95 ± 15.22	0.190	0.312
	6 weeks	47.26 ± 16.55	50.22 ± 15.34	0.556	
	Δ_{WMFT}	14.63 ± 11.56	11.27 ± 9.89	0.328	
	p	< 0.001*	< 0.001*	-	
TIS	Baseline	10.89 ± 6.44	14.00 ± 5.63	0.112	0.662
	6 weeks	17.68 ± 4.74	18.00 ± 4.92	0.836	
	Δ_{TIS}	6.78 ± 4.25	4.00 ± 4.14	0.040	
	p	< 0.001*	< 0.001*	-	

Δ: 6 weeks-baseline; *ES*: effect size; *FMA-UE*: Fugl-Meyer Assessment–Upper Extremity; *TIS*: Trunk Impairment Scale, *WMFT*: Wolf Motor Function Test

*Statistically significant

The trunk has an important effect on motor movements and interacts with many physiological components and nerve tissues. It supports the voluntary controlled movement of the extremities during functional activities [25]. During extremities motions, trunk-stabilizing muscles create and transmit strength from large to tiny body parts. The central location of these muscles helps regulate the proximal stability necessary for certain distal segment motions. Inadequate trunk control causes compensatory mechanisms to come into play with the effect of other body structures during functional activities, with a subsequent loss in movement performance [26]. Trunk stability also plays a primary role in maintaining upper extremity functions [27]. Nearly two thirds of stroke patients have been reported to be affected in daily living activities due to decreased upper extremity movements and functions [28]. Trunk stabilization can be improved actively with exercises as well as passively with auxiliary materials [29]. Improvements in upper extremity function and performance have been reported when the trunk of stroke patients was stabilized with external support [25]. In another study where the trunk was passively stabilized, the rehabilitation program allowed shoulder and elbow movements to be more coordinated, and the movements approached a relatively normal pattern [30]. TIS scores and upper extremity functions were increased in stroke patients who underwent virtual reality-based active trunk stabilization exercises. In that study, it was emphasized that the increase in gains, especially for the upper extremity, is due to increased trunk stability and the participation of large muscle groups in high-frequency active movement [31]. In the current study, the trunk control of the patients was observed to increase as a result of the ITR program applied to both groups. An ITR program for abdominal muscles, back extensors, and muscles around the scapula was applied to all the cases. The improvement in the TIS score in both groups after the rehabilitation programs was attributed to the increase in strength due to the force distribution in the proximal stabilizer muscles. In addition, more conscious, active, and intense, repetitive use of the muscles was ensured with the programs.

Motor strategies compensate the loss of upper extremity ability due to stroke. In addition to studies suggesting that these strategies contribute to the development of synergy,

Table 3 Correlation coefficient between TIS, FMA-UE, and WMFT

Variables	Robotic				Conventional			
	FMA-UE		WMFT		FMA-UE		WMFT	
	r	*P*	*r*	*p*	*r*	*p*	*R*	*p*
TIS	-	0.226	-	0.965	-	0.997	-	0.444

FMA-UE: Fugl-Meyer Assessment–Upper Extremity; *TIS*: Trunk Impairment Scale; *WMFT*: Wolf Motor Function Test attention was drawn to the deterioration in motor function in cases with increased trunk involvement. The literature reports the multidimensional positive effects of trunk rehabilitation in different pathologies [32]. In addition, combined approaches with trunk rehabilitation showed improvement in hemiparetic arm functions [33, 34]. No study was found that included the combination of intensive trunk rehabilitation with robotic rehabilitation-assisted upper extremity rehabilitation or compared it with conventional therapy. Our study is original in this respect and we believe contributes to the literature. Robotic rehabilitation practices include active, functional, and multi-repetitive, task-specific exercises. Robotic rehabilitation interventions for the upper extremity are alternative methods to conventional rehabilitation techniques used to restore the functional ability of the extremity. Moreover, the ability of the cases to adapt to technology may affect RR's success. The individuals aged 40–85 years were in the study [35] because there may be differences in the technology use and adaptation skills of people aged 40 and over, and most of the stroke studies included individuals over the age of 40. Thus, it prevented the possibility of young individuals being assigned to the RR group. In addition, the authors wanted the partial narrowing of the age range to increase the probability of homogeneous distribution of the groups. On the other hand, this study only included people in the subacute period (from 1 to 6 months). Although our analyses differed between the groups in terms of stroke onset, all participants were included in the study according to these inclusion criteria. Since the evaluation and applications were made after randomization, we could not interfere with the groups in terms of this parameter. And unfortunately, our limited case numbers for each group did not allow analysis according to the subacute stroke's different terms. We think that in studies with larger cohorts, the results to be obtained in the early and late stages of the subacute period can be examined.

The second aim of this study was to compare the superiority and clinical preferability of conventional rehabilitation and robotic rehabilitation applied in addition to intensive trunk rehabilitation. For this purpose, a kind of passive exoskeleton robotic system device was used in this research. Normally, the upper limb robotic systems that are now in use can be loosely divided into three categories: active systems, passive systems, and interactive systems [36]. In passive exoskeleton systems, the patient's active participation is essential, and the device only provides movement easily. Most of the studies in the literature have been carried out with active exoskeleton devices [37, 38]. It is a known fact that active movement with passive exoskeleton systems induces the plasticity ability of the brain. However, the patient should have minimal active movement skills at the beginning in these systems. For this reason, individuals with high spasticity were not included in the study. Because high spasticity level is a factor that directly affects the active joint range of motion. The absence of any adverse events (increased spasticity, etc.) in our study is another finding that supports the use of a passive exoskeleton system. The effects of robotic rehabilitation have often been compared with conventional approaches in the literature. Aprile et al. examined the effects of robotic rehabilitation and traditional physiotherapy applications on upper extremity functions and range of motion in patients with subacute stroke, and emphasized that there was no superiority of one method over the other at the end of the study [39]. In a study conducted by Taravati et al., while robotic rehabilitation applied five times a week for 4 weeks increased upper extremity motor functions more than the conventional rehabilitation program, this increase was not statistically different and was similar to the current study results [40]. In another study comparing the efficacy of a 12-week robotic rehabilitation program and a general physiotherapy program in patients with chronic stroke, it was stated that while robotic rehabilitation was superior in improving motor functions, the results were worse compared to the intensive rehabilitation group. In contrast to the publications mentioned above, some studies have stated that robotic rehabilitation is superior to conventional methods. When robotic rehabilitation applied to stroke patients is combined with traditional methods, it has been shown to cause a greater increase in upper extremity abilities compared to the groups applied with conventional methods only [41]. A possible reason for this is that the positive effects of exercise may have accumulated with the successive application of both conventional and robotic rehabilitation. At the same time, robotic rehabilitation may have positively affected the motivation parameter that directly affects the treatment. Daunoraviciene et al. also reported that robotic rehabilitation improved the functional independence of individuals more than the control group [42]. The different results of robotic rehabilitation studies in the literature may be attributed to the fact that there are 141 different robotic or mechanical rehabilitation devices defined for this purpose [43]. Although the current study results showed no significant difference between the groups, the gains were relatively higher after robotic rehabilitation. These gains may have occurred depending on the advantages and disadvantages of the applied treatment programs compared to each other. Although we could not find a study on the application of combined robotic rehabilitation with trunk stabilization training, research results on trunk rehabilitation applied together with conventional rehabilitation applications emphasize the benefit of this approach in both the lower and upper extremities. Min et al. used a trunk stabilization training robot in stroke rehabilitation and found that lower extremity balance and function improved more than with traditional approaches [44]. Also, Lee et al. compared the effects of upper-extremity exercises taken in addition to conventional rehabilitation and trunk training on a moving surface. They have been shown that trunk exercises performed on unstable surfaces improve trunk control, arm function during sitting, and walking more in subacute stroke [33]. According to the this study results, improvements were seen in the TIS scores and upper extremity motor functions of both groups. Although these improvements were relatively higher in the RR group, neither treatment method was found to be superior to the other at the end of the study. We suggest new studies be conducted with these systems in terms of supporting the active movement and providing patient participation and motivation in suitable cases with minimal functional skills.

In the success of the training given within the scope of this research, being able to show sufficient cognitive performance was as important as motor learning to reach the target. For a successful and effective rehabilitation process in the post-stroke period, no matter which method is used, the cognitive level must be sufficient [45]. Therefore, the study only included patients with MMSE scores of > 20. The advantages of robotic rehabilitation include allowing multiple repetitive and purposeful activities, less supervision of patients is required, the treatment intensity can be adjusted to the desired level, and there is visual feedback showing personal progression, thereby increasing the patient's motivation and adherence to the treatment. In contrast, conventional treatment approaches have disadvantages such as taking a long time for repetitive movements, decreased treatment effectiveness due to loss of motivation, and the fact that treatment effectiveness is largely dependent on the clinical knowledge and skills of the therapist [40]. The differences between the two methods may have contributed to the results obtained.

This study had some limitations. First, the study only included the short-term effects of robot-assisted systems, and there was no long-term outcome assessment of how long the effect lasted after the treatment program. Secondly, endurance tests in the flexion and extension directions of the trunk could support the TIS score. At this point, these evaluations could not be made because the test positions may pose a risk for the patients and there was a need for upper extremity functionality. Also the lack of muscle assessment results can be considered as another limitation of the study. The patient's muscle strength was routinely evaluated with Manual Muscle Testing (MMT) due to the lack of objective measuring devices in stroke. In the literature, while it has been reported that peak and mean torque obtained with the use of an isokinetic dynamometer, objective assessment tools, are reliable in evaluating post-stroke muscle strength, the MMT has low objectivity and reliability [46, 47]. Moreover, it is also stated that it is insufficient in terms of identifying low-level improvements. On the other hand, the decrease in motor control manifests itself as a problem in producing correct motor output in the paretic limb after stroke. There is new evidence that impairment in motor control affects functional capacity, not strength, in patients [48]. Although strength improved significantly in high-functioning stroke patients, motor control and functional mobility impairments continued. Rehabilitation interventions that assess and treat motor control can potentially improve functional outcomes in stroke patients. Due to these reasons, and especially the lack of assessment tools, we cannot include the muscle strength assessment in the methodology. In the future studies, the effect of robotic rehabilitation on muscle strength can be investigated with isokinetic measurements, if possible.

Conclusion

This study demonstrated that, when combined with intensive trunk rehabilitation, robot-assisted systems, which are suggested as a stand-alone therapeutic technique, provided the same results as intensive trunk rehabilitation and traditional therapy combinations in the short term. The advantages of these robotic rehabilitation systems can be listed as the ability to adjust the treatment intensity, a lesser need for clinical observation, and the ability to provide objective data and feedback to the patients both during the session and at the end of the treatment programs. However, robotic rehabilitation systems are expensive, difficult to access, and require clinical expertise. From this perspective, it is worth questioning whether robotic rehabilitation added to intensive trunk rehabilitation as a treatment approach in stroke patients is preferable to conventional approaches added to intensive trunk rehabilitation. Moreover, when robotic rehabilitation is combined with additional interventions such as intensive trunk rehabilitation, it is essential to investigate if the real effect is due to the robotic rehabilitation or the accumulation of positive effects from excessive movement or force spread associated with trained muscles. In terms of accessibility and cost-effectiveness, it may be more appropriate to choose more advantageous and cheaper methods as a treatment approach. There is a need for more comprehensive studies to examine the short- and long-term effects of the interventions discussed in this study according to the post-infarction time in subacute stroke patients.

Declarations

Ethical approval Marmara University Clinical Research Ethics Committee approved this study with protocol ID: 168 at 06.09.2021.

Conflict of interest The authors declare no competing interests.

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