Research Article (Araştırma Makalesi)

The Effect of Robot-assisted Virtual Reality Therapy on Improving Upper Limb Functions, Pain, and Daily Living Activities in Stroke Patients

Robot Destekli Sanal Gerçeklik Terapisinin İnme Hastalarında Üst Ekstremite Fonksiyonları, Ağrı ve Günlük Yaşam Aktivitelerini İyileştirmedeki Etkisi

Canan AVCI[1] Kadriye ONES[1] Mustafa Aziz YILDIRIM[1]

[1] Istanbul Physical Medicine and Rehabilitation Training Research Hospital, Department of Physical Medicine and Rehabilitation, Istanbul, Türkiye

Özet

Amaç: Bu çalışmada amacımız inmeli hastalarda konvansiyonel tedaviye eklenen robot yardımlı sanal gerçeklik terapisinin (RYSGT) ağrı, fonksiyonel durum ve günlük yaşam aktiviteleri üzerine etkisini incelemektir.

Gereç ve Yöntemler: Çalışmaya 40 inmeli hasta dahil edildi. Hastalar iki gruba ayrıldı. Grup I konvansiyonel terapi (4 hafta boyunca haftada 5 gün, günde 1 saat) ve ek olarak 4 hafta boyunca haftada 5 gün, günde 30 dakika olmak üzere 20 seans üst ekstremite RYSGT'si aldı. Grup II ise sadece konvansiyonel terapi aldı. Tüm hastalar tedavi öncesi ve sonrası değerlendirildi. Hastaların ağrılarını değerlendirmek için Görsel Analog Skalası (VAS), günlük yaşam aktivitelerini belirlemek için Barthel İndeksi (BI) ve üst ekstremite motor fonksiyonlarını değerlendirmek için Fugl Meyer Üst Ekstremite Değerlendirmesi (FMA-UE) kullanıldı.

Bulgular: Hastaların ortalama yaşı 58,25 ± 14,7 yıl idi. Cinsiyet, eğitim durumu, inme sonrası geçen süre, lezyon tarafı ve lezyon tipi açısından iki grup arasında anlamlı bir fark yoktu (p>0,05). Grup I ve II'de tedavi sonrası (AT) tüm parametreler tedavi öncesine (BT) göre anlamlı (p<0,05) artış gösterdi. Ancak VAS, BI ve FMA-UE skorlarındaki BT/AT değişimi iki grup arasında anlamlı olarak farklı değildi (p>0,05).

Sonuç: Bu çalışma, RYSGT'nin kronik inmeli hastaların fonksiyonel durumunu, günlük yaşam aktivitelerini ve ağrı skorlarını iyileştirdiğini, ancak tedaviden sonra iki grup arasında fark olmadığını gösterdi. RYSGT yaklaşımıyla fonksiyonel iyileşmeler kaydedilmesine rağmen, tek başına geleneksel tedaviye üstün değildi.

Anahtar kelimeler: Robot Destekli Terapi, Rehabilitasyon, İnme, Üst Ekstremite, Sanal Gerçeklik

Abstract

Objective: In the present study, our aim is to examine the effect of robot-assisted virtual reality therapy (RAVRT) added to conventional treatment on pain, functional status, and daily living activities (DLA) in stroke patients.

Material and Methods: The study included 40 patients with stroke. The patients were divided into two groups. Group I received conventional therapy (5 days a week for 4 weeks, 1 hour a day) and additionally 20 sessions of upper extremity RAVRT for 4 weeks, 5 days a week, 30 minutes a day. Group II received only conventional therapy. All patients were evaluated before and after the treatment. The Visual Analogue Scale (VAS) was used to evaluate the patients' pain, the Barthel Index (BI) to determine DLA, and the Fugl Meyer Assessment Upper Extremity (FMA-UE) to evaluate the UE motor functions.

Results: The mean age of the patients was 58.25 ± 14.7 years. There was no significant difference between the two groups in terms of gender, educational status, time after stroke, lesion side, and lesion type (p>0.05). In groups I and II, after the treatment (AT), all parameters showed a significant (p<0.05) increase when compared to values before the treatment (BT). However, the BT / AT change in VAS, BI, and FMA-UE scores was not significantly different (p>0.05) between the two groups.

Conclusion: This study showed that RAVRT improved functional status, activities of daily living, and pain scores of chronic stroke patients, but there was no difference between the two groups after treatment. Although functional improvements were noted with the RAVRT approach, it was not superior to conventional therapy alone.

Keywords: Robot-Assisted Therapy, Rehabilitation, Stroke, Upper Extremity, Virtual Reality

Correspondence: Canan AVCI, İstanbul Fiziksel Tıp ve Rehabilitasyon Eğitim Araştırma Hastanesi, Fiziksel Tıp ve Rehabilitasyon Anabilim Dalı. Bahçelievler Mahallesi, Adnan Kahveci Blv. No : 145, 34186 Bahçelievler /Istanbul, Türkiye

Phone: +90 2124965000 **e-mail:** cnndr@hotmail.com

ORCID No (Respectively): 0000-0003-4544-0133, 0000-0001-9438-4428, 0000-0001-6688-7626

Submission date: 24.01.2025

Acceptance date: 26.03.2025

DOI: 10.17517/ksutfd.1626261

INTRODUCTION

Loss of motor function in the upper extremities (UE) is the most common and destructive consequence of disability due to stroke. The arm is more affected than the leg in stroke patients. One of the goals of stroke rehabilitation is to gain independence in DLA, so due importance should be given to UE rehabilitation (1). Various techniques are used for the UE rehabilitation. These are intensive, high-repetitive task-oriented therapies: constraint-induced movement therapy (CMIT), functional electrical stimulation (FES), virtual reality (VR), and robot-assisted therapy (RAT). Functional improvement of patients is associated with cortical reorganization, and active participation of patients increases this. This reorganization, called neuroplasticity (2). UE-RAT provides frequent repetition, intensive training, and interactive feedback (3). Robotic therapy has been shown to affect the results positively. These systems allow continuous and repetitive therapy to be performed with less effort and the less cost. In these systems, visual and auditory biofeedback can be provided with VR. Thus, motor learning is increased with neural plasticity (4). VR refers to the process of complete immersion of the person or patient in a virtual scenario as close as possible to the real world, using various devices. VR-based rehabilitation has been used with many neurological diseases, especially stroke patients, and there are many studies supporting its beneficial effects on patients (5,6).

RAT is an effective neurorehabilitation approach that has been widely used recently, enhances the effects of physical therapy, and facilitates motor recovery (7). Many studies on RAT treatment have been examined (8,9). Results vary according to the type of robot, study design, and characteristics of the patient. Many researchers showed that with a robot-assisted VR rehabilitation program, although the improvement in DLA was limited, the movement and muscle strength of the upper extremities increased. This can be explained by the limitation of UE-RAT in the proximal part of the UE. For functional improvement, coordination between the proximal and the distal parts is required (10-12).

The study aims to reveal how these new technologies affect the functional recovery of the UE, pain, and DLA.

MATERIALS AND METHODS

This is a prospective controlled study of patients with stroke inpatients in the Istanbul Physical Medicine and Rehabilitation Training Research Hospital, Department of Physical Medicine and Rehabilitation. Preliminary information was given to the participants about the study. Written informed consent was signed voluntarily by all participants or their immediate family members. 68 stroke patients who developed hemiplegia after cerebrovascular accident (CVA) and underwent inpatient rehabilitation were included in the study and were evaluated prospectively. 40 of these patients met the inclusion criteria **(Figure 1)**.

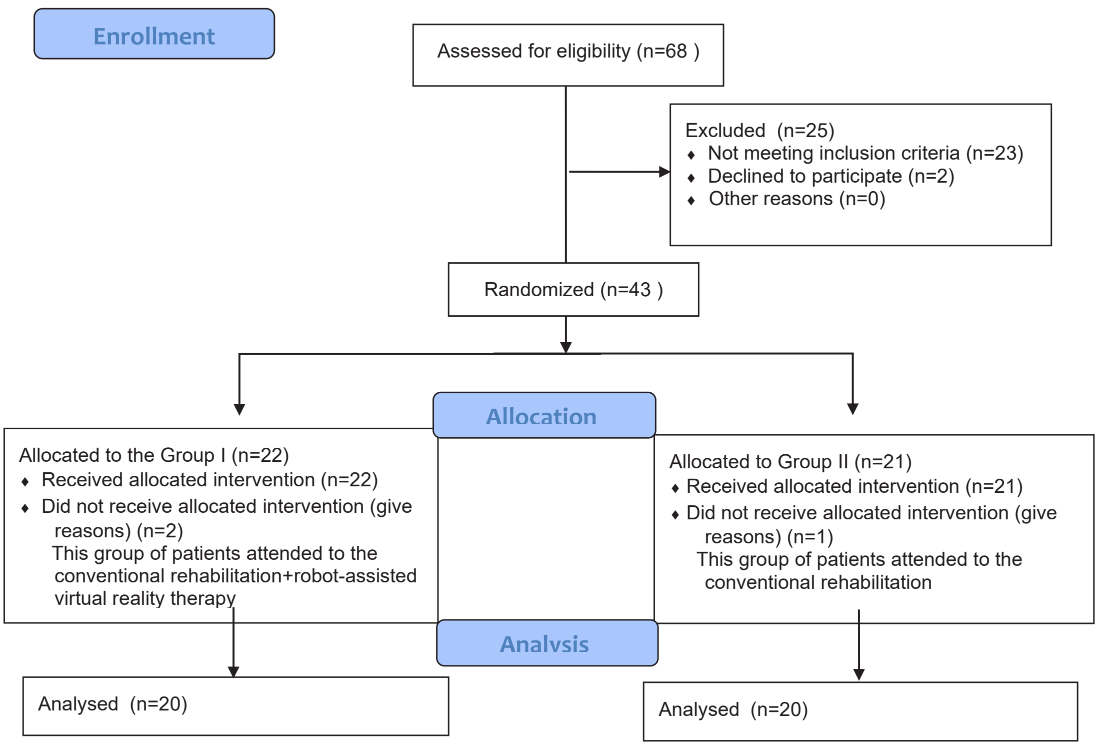

Figure 1. Flow diagram of Group I and Group II.

Participants were divided into two groups of 20 patients using the "Random Number Generator Program". Group I (n=20) received a total of 20 sessions of RAVRT (30 minutes per day) and conventional treatment (30 minutes per day). Group II (n = 20) received an equal number of sessions of conventional treatment (1 hour per day) only. The treatment program was conducted 5 times per week for one month. Conventional therapy consists of exercises that include passive or active range of motion exercises, muscle strengthening, gross motor training, grasping and releasing, and stretching for the affected side of the upper limb, as well as activities of daily living.

Inclusion criteria were as follows: ischemic or hemorrhagic CVA, 18-85 year old patients with a diagnosis of stroke, Brunnstrom UE motor stage ≥3, at least 3 months had passed after CVA, and modified Ashworth Score ≤2. The Brunnstrom stage ≥3 patients were included because patients must have at least level 3 motor movement to be able to perform the VR program on the Armeo Spring device. This is a prerequisite for the completion of the given tasks.

Exclusion criteria were as follows: aphasic patients, cognitive impairment, standardized mini-mental test score <24, contracture and/or deformity in the UE, and patients diagnosed with KBAS.

Armeo Spring device

The Armeo Spring device (http://www.hocoma.com/en/products/armeo/armeo-spring/; see also Figure 2) is an arm orthosis equipped with various components, including a pressure-sensitive grip. A spring-loaded mechanism provides adjustable weight support for the arm requiring therapy, thus facilitating functional arm movements.

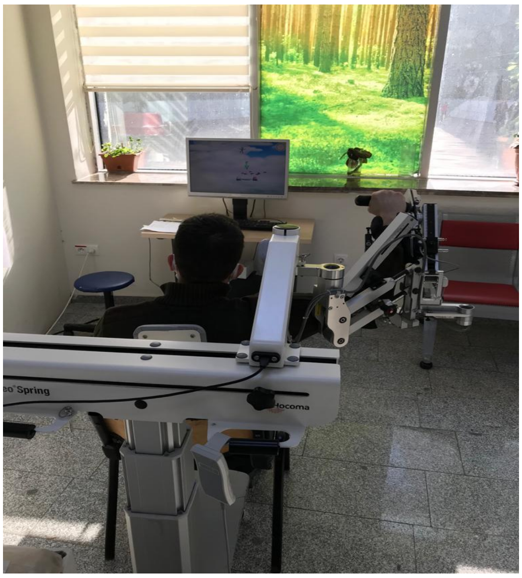

Figure 2. The Armeo Spring is an exoskeleton apparatus with an integrated spring mechanism allowing variable upper limb gravity support.

Adjustable ergonomic arm support functions as an exoskeleton equipped with integrated springs. It extends from the shoulder to the hand and enhances the full range of motion and neuromuscular control. This device assists in active movement over a wide 3-dimensional range and balances the weight of the arm with a consistent force. The pressure-sensitive handgrip is useful for exercises, connecting to computer software and games, and functional training for daily tasks. It also measures movement and functionality, allowing for intensive grip and release exercises in the early stages of rehabilitation. The device was attached to the hemiplegic upper extremities of the patients with upper and forearm cuffs. Adjusted for arm, forearm, and wrist lengths. Exercise programs suitable for the functional status of the patients were determined, and they were included in an exercise program in the form of a game (VR) with the monitor placed opposite them. The patients were enrolled in functional exercise programs that included activities such as collecting rain in a glass, grating vegetables, playing goalkeeper, cleaning the stove, watering flowers, cleaning windows, fishing, and exploring various landscapes **(Figure 2)**.

Evaluation Parameters

Before and following treatment, the patients were evaluated. Evaluations were performed by a single physician while the patient was in the inpatient clinic. During the evaluations, the following parameters were recorded.

Pain Inquiry

In this study, a 10 cm line called the VAS, which is among the visual methods, was used for pain questioning. On this line, "0" indicates painlessness and "10" indicates unbearable pain.

Daily Living Activities Evaluation

BI has been adapted for Turkish patients and includes 10 items that evaluate DLA and mobility. Feeding, washing, dressing, personal care, bowel and bladder care, sitting on the toilet, transferring from a wheelchair to a bed, walking on level ground, and climbing stairs are evaluated. A score is made based on whether or not the patient receives assistance while performing these tasks. A score between 0-20 indicates fully dependent, 21-61 points indicate highly dependent, 62-90 points indicate moderately dependent, 91-99 points indicate mildly dependent, 100 points indicate fully independent (13).

Fugl-Meyer Assessment -Upper Extremity (FMA-UE)

The FMA-UE evaluates the hemiparetic arm's mobility, including reflexes, the appearance of synergies, and each of the upper limb's isolated movements, including grasp. Items that assess patients' dysmetria, coordination, and velocity are also included in this measure. It is designed to evaluate reflex activities, movement control, and muscle strength after the stroke in the UE. It consists of 33 items, and each item takes a value between 0-2. No performance is indicated by a score of 0, partial performance is indicated by a score of 1, and complete performance is indicated by a score of 2. As a result of the total score, scores lower than 31 indicate weak capacity, scores between 32-47 indicate limited capacity, scores between 48-52 indicate remarkable capacity, and scores between 53-66 indicate full capacity (14).

Statistical analysis

The mean, standard deviation, median, minimum, maximum, frequency, and ratio values were employed in the data's descriptive statistics. The Kolmogorov-Smirnov test was used to measure the variables' distribution. The quantitative data were analyzed using the independent samples t-test and the Mann-Whitney U test. Repeated measurements were analyzed using the Wilcoxon and McNemar tests. Qualitative data were analyzed using the chi-square test, and when the chi-square test requirements were not satisfied, the Fisher test was employed. The analysis was conducted using the SPSS 22.0 program.

RESULTS

There was no notable difference between group I and group II regarding age, gender, marital status, dominant hand, event duration, standardized mini-mental score, cause, or hemiplegic side ($p < 0.05$) **(Table 1)**.

Table 1. Sociodemographic and clinical features of patients with conventional treatment +robot-assisted virtual reality therapy group and conventional treatment group

		Conventional treatment+ robot-assisted virtual reality therapy			Conventional treatment			p
		Mean.±SD/n-%		Med(Min-Max)	Mean.±SD/n-%		Med(Min-Max)	
Age		58,2 ± 14,1		60 (27 - 76)	58,3 ± 15,3		60 (18 - 77)	0,914
Gender	Female	14	70%		12	60%		0,507
	Male	6	30%		8	40%		
Marital Status	Married	17	85%		14	70%		0,256
	Single	1	5%		2	10%		
	Widow	2	10%		4	20%		
Dominant Hand	Right	18	90%		18	90%		1
	Left	2	10%		2	10%		
Event duration (month)		13,3 ± 15,6		8 (3 - 60)	13,1 ± 15,8		7 (3 - 60)	0,807
Standardized mini mental test		26,3 ± 2,2		26 (24 - 30)	25,3 ± 2,0		25 (24 - 30)	0,141
Etiology								
Ischemic CVA		15	75%		15	75%		1
Hemorrhagic CVA		5	25%		5	25%		
Hemiplegia Side	Right	8	40%		7	35%		0,744
	Left	12	60%		13	65%		
Brunnstorm Stage								
Upper extremity before treatment		4,0 ± 0,9		4 (2 - 5)	3,8 ± 0,8		4 (3 - 5)	0,491

Mann-whitney u test/Wilcoxon test
VAS: visual analog scaleMean.±SD : mean+ standard deviation Med(Min-Max): median (minimum-maximum)

VAS scores obtained before and after the treatment were not significantly different in group I and group II ($p > 0.05$). The VAS score for shoulder pain decreased significantly after treatment in both groups ($p < 0.05$) when compared to BT **(Table 2)**. The BT/AT change in VAS scores was not significantly different ($p > 0.05$) between the two groups.

BI calculated before and after the treatment was not significantly different in group I and group II ($p > 0.05$). BI increased significantly ($p < 0.05$) after the treatment in both group I and group II when compared to BT. The BT/AT change in BI was not significantly different ($p > 0.05$) between the two groups **(Table 3)**.

FMA-UE arm score, wrist score, hand score, coordination and speed score, and total score calculated before and after the treatment were not significantly different ($p > 0.05$) between group I and group II. FMA-UE scores increased significantly ($p < 0.05$) after the treatment in Groups I and II compared to pre-treatment. The BT/AT change in all FMA-UE scores was not significantly different ($p > 0.05$) between the two groups **(Table 4)**.

DISCUSSION

In this study, we investigated the effect of RAVRT on pain, motor and functional status, and DLA of patients with stroke. All patients completed the interventions without any major problems. The main findings of our study were that significant improvement was observed in VAS, Brunstromm, FMA-UE, and BI after the rehabilitation in both groups. On the other hand, there was no noticeable difference in DLA, motor and functional condition, or pain between the two groups. Pain is one of the important symptoms affecting the rehabilitation process. Shoulder pain masks the improvement in the patient's motor function. As a result, it affects the rehabilitation program of the patient and extends the rehabilitation duration (15). In the literature, the frequency of hemiplegic shoulder pain varies between 24-64% (16). Analysis of the patients' VAS pain scores

Table 2. Improvement of VAS values in patients with conventional treatment + +robot-assisted virtual reality therapy group and conventional treatment group

	Conventional treatment+ robot-assisted virtual reality therapy		Conventional treatment		p
	Mean.±SD/n-%	Med(Min-Max)	Mean.±SD/n-%	Med(Min-Max)	
Shoulder VAS					
Before Treatment (BT)	1,2 ± 1,7	0 (0 - 4)	1,1 ± 1,7	0 (0 - 5)	0,911
After Treatment (AT)	0,6 ± 1,2	0 (0 - 4)	0,5 ± 0,8	0 (0 - 2)	0,725
BT/AT Difference	0,6 ± 1,1	0 (0 - 4)	0,6 ± 1,1	0 (0 - 3)	0,986
p	***0,034***		***0,041***		

t test/Mann-whitney u test/Chi-Square test (Fischer test)

Mean.±SD: mean+ standard deviation Med(Min-Max): median (minimum-maximum) CVA: cerebrovascular accident

Table 3. Improvement of Barthel Index scores in patients with conventional treatment +robot-assisted virtual reality therapy group and conventional treatment group

	Conventional treatment+ robot-assisted virtual reality therapy		Conventional treatment		p
	Mean.±SD/n-%	Med(Min-Max)	Mean.±SD/n-%	Med(Min-Max)	
Barthel Index					
Before Treatment (BT)	69,0 ± 21,3	73 (15 - 100)	65,0 ± 24,1	65 (5 - 100)	0,615
After Treatment (AT)	80,0 ± 18,7	85 (25 - 100)	73,3 ± 21,7	78 (10 - 100)	0,248
BT/AT Difference	11,0 ± 10,3	10 (0 - 40)	3,8 ± 0,8	5 (0 - 35)	0,319
p	***0,000***		***0,001***		

Mann-whitney u test / Wilcoxon test
Mean.±SD : mean+ standard deviation Med(Min-Max): median (minimum-maximum)

Table 4. Improvement of VAS values in patients with conventional treatment + +robot-assisted virtual reality therapy group and conventional treatment group

		Conventional treatment+ robot-assisted virtual reality therapy		Conventional treatment		p
		Mean.±SD/n-%	Med(Min-Max)	Mean.±SD/n-%	Med(Min-Max)	
FMA-UE						
Arm	BT	21,6 ± 5,2	21 (11 - 29)	22,3 ± 5,9	23 (12 - 30)	0,664
	AT	26,3 ± 5,8	27 (14 - 34)	25,9 ± 7,0	28 (12 - 36)	0,839
BT/AT Difference		4,7 ± 2,9	5 (0 - 11)	3,6 ± 3,3	3 (0 - 10)	0,211
p		***0,000***		***0,001***		
Wrist	BT	2,6 ± 1,8	3 (0 - 6)	3,9 ± 2,3	5 (0 - 7)	0,051
	AT	4,0 ± 3,0	4 (0 - 10)	4,9 ± 3,0	5 (0 - 10)	0,268
BT/AT Difference		1,4 ± 1,6	1 (0 - 5)	1,0 ± 1,3	1 (0 - 4)	0,565
p		***0,003***		***0,005***		
Hand	BT	6,9 ± 4,1	7 (1 - 13)	7,1 ± 3,3	8 (0 - 12)	0,892
	AT	9,3 ± 3,9	10 (3 - 14)	8,8 ± 4,0	10 (0 - 14)	0,703
BT/AT Difference		2,4 ± 2,2	3 (0 - 6)	1,7 ± 1,7	2 (0 - 5)	0,337
p		***0,001***		***0,002***		
Coordination and speed	BT	2,7 ± 1,3	3 (0 - 5)	3,1 ± 1,2	3 (1 - 6)	0,512
	AT	3,5 ± 1,4	3 (1 - 6)	3,8 ± 1,5	4 (1 - 6)	0,415
BT/AT Difference		0,8 ± 1,0	0 (0 - 3)	0,7 ± 0,8	1 (0 - 2)	0,906
p		***0,006***		***0,004***		
Total	BT	34,3 ± 8,4	34 (19 - 49)	36,5 ± 10,8	38 (18 - 49)	0,357
	AT	43,0 ± 12,0	41 (20 - 63)	43,2 ± 14,0	45 (18 - 66)	0,903
BT/AT Difference		8,7 ± 5,4	8 (0 - 18)	6,8 ± 5,9	5 (0 - 18)	0,212
p		***0,000***		***0,000***		

Mann-whitney U test / Wilcoxon test
FMA-UE: Fugl Meyer Assessment Upper Extremity BT: Before treatment AT: After Treatment
Mean.±SD: mean+ standard deviation Med(Min-Max): median (minimum-maximum)

revealed a statistically significant reduction in pain in both groups and no significant variation in VAS difference scores between the groups. With these findings, we can comment that in the worst case, the robotic rehabilitation program applied to patients does not have a treatment side effect in terms of pain. The goal in stroke rehabilitation is to provide the highest level of independence in the DLA, despite existing motor impairments. It has been shown that the level of functional independence gained as a result of the rehabilitation program in patients with stroke is largely related to UE and hand motor deficiencies. To maintain the basic functions in daily life, the use of the UE is important, and UE paralysis causes problems in maintaining DLA. In stroke rehabilitation, it should be for the individual to attain the highest level of independence in activities of daily living, despite existing motor disabilities (17). In this study, DLA were evaluated with BI. Both groups ' post-treatment scores were statistically higher than the initial scores. While this increase was 11 points in group I patients who received UE-RAT, it was 8.3 points in group II. Although the increase was greater in group I, this was not statistically significant.

Ju-Hong Kim et al.'s study investigated the effect of the VR program on function in stroke patients. A total of 24 patients were included, and two groups were formed. Conventional treatment was applied to both groups, and the study group also applied a VR-based video game exercise program. UE functional assessment was measured using the Fugl-Meyer Assessment and Manual Function Test, and DLA was measured with SIS (Stroke Impact Scale), unlike our study. Stroke patients who underwent extra training with VR games demonstrated significantly greater improvements in DLA than those who received only conventional rehabilitation therapy. Similar to our study, no significant difference was observed between the 2 groups in UE motor functions (18).

VR has become an advantageous treatment modality by providing many features that are important in neurological rehabilitation, such as task-oriented, functional, and repetitive training. Functional recovery, whether spontaneous or secondary to intensive rehabilitation, is maintained through neuroplasticity and the restructuring of neurons in the damaged brain in adults (19,20). Studies on the use of VR for rehabilitation purposes are increasing gradually. In the study conducted by Colomer et al., the effect of Armeo Spring in chronic stroke patients was evaluated. 23 patients with ischemic or hemorrhagic stroke were included in the study, 36 sessions of UE-RAT were applied 3 times a week, 1-hour sessions, and conventional treatments continued at the same time. Patients were followed up before and after the treatment and at the fourth month. The functional evaluation of the patients was investigated with FMA-UE, and the spasticity was evaluated with MAS. Statistical analysis showed a significant improvement in functional scales; however, there was no significant improvement in muscle tone (2). In the randomized controlled study of Lum et al., RAT and conventional therapy were compared in UE rehabilitation in stroke patients. 27 patients were included in the study, 24 sessions of RAT were applied to the study group, and 24 sessions of UE neurodevelopmental therapy were applied to the control group. As a result of the study, a significant improvement was observed in FMA-UE in the 1st and 2nd months after the treatment in the study group compared to the control group, but no significant difference was found in the 6th month evaluation (21). The lack of long-term control is a limitation of our study.

The combination of RT and VR interventions shows potential to improve UE function; however, additional research is needed to confirm these findings, investigate the underlying mechanisms, and assess the consistency and applicability of the results (22).

Masiero et al conducted a study of 35 patients to evaluate the effect of robotic therapy on motor development and functional activities in patients after acute stroke who received robot-assisted rehabilitation in the UE. In addition to the conventional treatment program, robotic (NeReBot) rehabilitation was applied to 17 patients included in the robotic treatment group, two sessions a day, 4 hours a week, and a total of 5 weeks. The robotic rehabilitation program focuses on the patient's shoulder and elbow movement patterns. In the control group of 18 patients, exercise therapy and robotic therapy were applied twice a week for 30 minutes. The patients were evaluated with FMA, FIM, Modified Asworth Scale, trunk control test, and muscle strength before and after the treatment and at 8-month follow-up. When compared to the control group, in patients after acute stroke who received robot-assisted rehabilitation in the UE, the method provided significant improvement in motor impairment and functional abilities, FMA proximal upper arm and FIM parameters, and these gains continued at the third and eighth months after the treatment. In this study, the treatment program consisting of conventional treatment (65% of the exercise time) and robotic rehabilitation (35% of the exercise time) showed similar results with the conventional treatment group in terms of motor recovery, DLA, and functional recovery of the hand (23).

Some researchers contend that robotic therapy is at least as effective as conventional therapy, while others have demonstrated that robotic systems yield better outcomes than conventional therapy. In this study, we found significant improvement in FMA-UE in both groups. Unfortunately, patients were evaluated before and after the treatment; follow-up results were not examined. In this case, we do not have a chance to predict the permanence of treatment results and make a comment on the improvement among the groups. This is one of the limitations of our study. Another limitation is the small sample size of patients.

After a four-week treatment program of 20 sessions, pain, DLA, and functional status scores increased in patients who received only conventional treatment, as well as patients in the robotic treatment group. The improvement in both treatment groups is not surprising, because the functional gains of the patients, taking more care to use their hands during DLA, and being encouraged in this direction, may have increased the awareness of the extremity that they normally use less and brought motor development. However, RAVRT did not lead to better outcomes compared with conventional rehabilitation. Therefore, it needs to be improved with new solutions and in clinical practice guidelines, especially in terms of applicability.

Ethical Approval: The study was prepared in accordance with the Declaration of Helsinki. Medical ethics committee approval was obtained from Bakırköy Dr

Sadi Konuk Training Research Hospital (protocol no: 136, date: 2015/08/31). This clinical trial was registered at ClinicalTrials. gov (Registration no. NCT05815823).

Conflict of Interest and Financial Status: There is no conflict of interest. No funding was received for this manuscript.

Author Contribution: This study was produced from Canan Avcı's medical specialization thesis. All authors contributed equally to the study.

REFERENCES

1. El-Kafy EMA, Alshehri MA, El-Fiky AA, Guermazi MA. The Effect of Virtual Reality-Based Therapy on Improving Upper Limb Functions in Individuals With Stroke: A Randomized Control Trial. Front Aging Neurosci. 2021;13:731343.
2. Colomer C, Baldoví A, Torromé S, Navarro MD, Moliner B, Ferri J, et al. Efficacy of Armeo® Spring during the chronic phase of stroke. Study in mild to moderate cases of hemiparesis. Neurologia. 2013;28(5):261-7.
3. Yoo DH, Kim SY. Effects of upper limb robot-assisted therapy in the rehabilitation of stroke patients. J. Phys. Ther. Sci 2015;27:677-679
4. Blank AA, French JA, Pehlivan AU, O'Malley MK. Current Trends in Robot-Assisted Upper-Limb Stroke Rehabilitation: Promoting Patient Engagement in Therapy. Curr Phys Med Rehabil Rep. 2014;2(3):184-195.
5. Rutkowski S, Kiper P, Cacciante L, Cieślik B, Mazurek J, Turolla A, et al. Use of virtual reality-based training in different fields of rehabilitation: A systematic review and meta-analysis. J Rehabil Med. 2020 19;52(11):jrm00121.
6. Abd El-Kafy EM, Alshehri MA, El-Fiky AA, Guermazi MA, Mahmoud HM. The Effect of Robot-Mediated Virtual Reality Gaming on Upper Limb Spasticity Poststroke: A Randomized-Controlled Trial. Games Health J. 2022;11(2):93-103.
7. Balasubramanian S, Klein J, Burdet E. Robot-assisted rehabilitation of hand function. Curr Opin Neurol. 2010;23(6):661-70.
8. Volpe BT, Lynch D, Rykman-Berland A, Ferraro M, Galgano M, Hogan N, et al. Intensive sensorimotor arm training mediated by a therapist or robot improves hemiparesis in patients with chronic stroke. Neurorehabil Neural Repair. 2008;22(3):305-10.
9. Prange GB, Jannink MJ, Groothuis-Oudshoorn CG, Hermens HJ, Ijzerman MJ. Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke. J Rehabil Res Dev. 2006;43(2):171-84.
10. Tseng KC, Wang L, Hsieh C, Wong AM. Portable robots for upper-limb rehabilitation after stroke: a systematic review and meta-analysis. Ann Med. 2024;56(1):2337735.
11. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. Lancet Neurol. 2009;8(8):741–54.
12. Adomavičienė A, Daunoravičienė K, Kubilius R, Varžaitytė L, Raistenskis J. Influence of New Technologies on Post-Stroke Rehabilitation: A Comparison of Armeo Spring to the Kinect System. Medicina (Kaunas). 2019;55(4):98.
13. Shah S, Vanclay F, Cooper B. Improving the sensitivity of the Barthel Index for stroke rehabilitation. J Clin Epidemiol. 1989;42(8):703-9.
14. Page SJ, Levine P, Hade E. Psychometric properties and administration of the wrist/hand subscales of the Fugl-Meyer Assessment in minimally impaired upper extremity hemiparesis in stroke. Arch Phys Med Rehabil. 2012;93:2373–2376.
15. Wanklyn P, Forster A, Young J. Hemiplegic shoulder pain (HSP): Natural history and investigation of associated features. Disabil Rehabil. 1996;18(10):497–501.
16. Sharma AK, Asthana SS, Deshmukh I. Impact of Ultrasound-Guided Suprascapular Nerve Block in Stroke Survivors With Hemiplegic Shoulder Pain Undergoing Neurorehabilitation: A Retrospective Case Series. Cureus. 2024;16(9):e69051.
17. Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty M. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev. 2017;11(11):CD008349.
18. Kim JH. Effects of a virtual reality video game exercise program on upper extremity function and daily living activities in stroke patients. J Phys Ther Sci. 2018;30(12):1408-1411.
19. Alashram AR. Combined robot-assisted therapy virtual reality for upper limb rehabilitation in stroke survivors: a systematic review of randomized controlled trials. Neurol Sci. 2024;45(11):5141-5155.
20. Taveggia G, Borboni A, Salvi L, Mule C, Fogliaresi S, Villafane JH, et al. Efficacy of robot-assisted rehabilitation for the functional recovery of the upper limb in post-stroke patients: a randomized controlled study. Eur J Phys Rehabil Med. 2016;52:767-73.
21. Lum PS, Burger CG, Shor PC, Majmundar M, Van der Loos M. Robot-assisted movement training compared with conventional therapy techniques fort he rehabilitation of upper-limb motor function after stroke. Arch Phys Med Rehabil. 2002;83:952-9.
22. Alashram AR. Combined robot-assisted therapy virtual reality for upper limb rehabilitation in stroke survivors: a systematic review of randomized controlled trials. Neurol Sci. 2024;45(11):5141-5155.
23. Masiero S, Celia A, Rosati G, Armani M. Robotic-assisted rehabilitation of the upper limb after acute stroke. Arch Phys Med Rehabil. 2007;88(2):142-9.