

The effects of robot-assisted arm training on upper limb functions in Parkinson disease

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ABSTRACT

Objectives: The aim of this study was to investigate the effect of robot-assisted arm training and recreational activities in addition to a conventional rehabilitation program on upper extremity functions.

Patients and methods: The three-arm, randomized controlled study was conducted between July 2017 and March 2019. Forty-five patients (25 males, 20 females; mean age: 65.7±8.3 years; range, 40 to 75 years) were randomized into three groups. The first group underwent a conventional rehabilitation program. The second group underwent a conventional rehabilitation program + robot-assisted arm training. The third group underwent conventional rehabilitation + robot-assisted arm training + recreational activities. Before and after the rehabilitation program, handgrip strength, pinch strength, nine-hole peg test, Frenchay arm test, Unified Parkinson's Disease Rating Scale (UPDRS), Parkinson's Disease Questionnaire-39 (PDQ-39), rapid alternating movements, fine finger movements, Disabilities of the Arm, Shoulder, and Hand, and Fatigue Severity Scale were investigated.

Results: In the first and second group, success was achieved in UPDRS mentation, behavior and mood, activities of daily living, motor examination subscales, PDQ-39 total score, emotional well-being, and activities of daily living subscales. Handgrip strength and nine-hole peg test performance also improved significantly. Tip pinch strength, fine finger movements test, and Frenchay arm test showed greater improvement in the third group.

Conclusion: Activities of daily living, upper extremity motor function, muscle strength, mental and emotional well-being improved in patients with Parkinson disease treated with robot-assisted arm in addition to conventional rehabilitation. Hand fine motor skills were improved in patients who attended to recreational activities in addition to conventional rehabilitation and robot-assisted arm training.

Keywords: Neurological rehabilitation, Parkinson disease, recreational activities, robot-assisted arm, upper extremity functions.

Parkinson disease (PD) is a chronic progressive movement disorder affecting several systems due to degeneration of dopaminergic neurons in the nigrostriatal pathway. The disease is among the most common neurodegenerative disorders. It usually begins at the sixth-eighth decades and affects approximately 1% of the population over 65 years.^[1]

Parkinson disease has four fundamental symptoms: resting tremor, rigidity, bradykinesia, and postural instability. Generally, the first findings

are resting tremor in one extremity, difficulty in fine skills of the hand, and slowdown of all movements and walking. Moreover, bradykinesia, freezing phenomenon, flexed posture, fatigue, sleep disturbances, autonomic disorders, lack of reciprocal movement, difficulty in swallowing and speech due to orofacial dysfunction, cognitive impairment, and depression may be observed.^[1]

Small hand muscles are affected in PD due to involuntary movements and slowdown of voluntary

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movements. Fine hand skills and coordination deteriorate. Patients have difficulty in grasping and releasing objects. Ultimately, they become unable to perform daily living activities such as buttoning, holding keys, tooth brushing, using fork and spoon, holding cups, and writing.^[2]

Addition of physical rehabilitation program along with medical treatment is essential for increasing quality of life, fine hand skills, and functional capacity.^[3]

The rehabilitation program in PD is tailored to each patient based on the symptoms, functional status, and stage of the disease. A conventional rehabilitation program should comprise exercises of range of motion (ROM), stretching, relaxation, strengthening, balance, and breathing along with occupational therapy, postural stability, and gait training.^[4]

The conventional rehabilitation program is not standardly applied, even if it is applied, the desired results in terms of functional development may not be achieved. Besides, there is no consensus about duration, intensity, and the content of conventional rehabilitation programs.

While there are only a few studies on the effects of robot-assisted arm training (Armeo Power; Hocoma AG, Volketswil, Switzerland) on the improvement of upper extremity functions and fine hand skills, improvements have been achieved in lower extremity robotic rehabilitation programs.^[5] The Armeo Power is a robot-assisted neurorehabilitation modality aiming to increase functionality of the upper extremity and is commonly used in patients with stroke, multiple sclerosis, brain injury, spinal cord injury, cerebral palsy, and PD. It has been reported to help improve daily living activities such as grasping objects, dressing, and eating.^[6,7]

Recreational activities are enjoyable activities that people do in their off-duty time.^[8] In this study, we aimed to improve upper extremity functions and fine hand skills along with increase in motivation and quality of life in patients with PD by means of recreational activities painting on wood with acrylic colors. In the light of these data, we aimed to evaluate the effect of Armeo Power and recreational daily living activities in addition to a conventional rehabilitation program on upper extremity functions in PD patients with upper extremity dysfunction.

PATIENTS AND METHODS

The three-arm, randomized controlled study evaluated a total of 60 patients with PD diagnosed in the Neurology Clinic and evaluated by Physical Medicine and Rehabilitation Clinic of the Kırıkkale University Faculty of Medicine between July 2017 and March 2019. Of these, 45 patients (25 males, 20 females; mean age: 65.7 ± 8.3 years; range, 40 to 75 years) who fulfilled the inclusion criteria and accepted to receive inpatient rehabilitation were enrolled in the study. Fifteen patients who did not accept hospitalization were excluded from the study. Patients were divided into three groups of 15 patients and received four-week rehabilitation programs of five days a week, 90 min daily. Inclusion criteria were as follows: (i) diagnosis of PD; (ii) being aged 20 to 85 years (regardless of sex); (iii) a Standardized Mini-Mental Test (SMMT) score of >24 ; (iv) PD with a modified Hoehn and Yahr stage (HYS) ≤ 3 . Exclusion criteria were as follows: (i) patients with no cooperation; (ii) having severe comorbidities (e.g., decompensated heart failure or decompensated kidney failure) and prominent disability affecting functionality (vision loss or hearing loss); (iii) having other diseases affecting upper extremity functions (inflammatory diseases, polyneuropathy, brachial plexus lesions, and loss of ROM due to a trauma). Written informed consent was obtained from all patients. The study was approved by the Kırıkkale University Clinical Research Ethics Committee (Date: 13.06.2017, No: 15/02) and produced from a master thesis. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The groups were randomized with sealed envelope method by choosing one of the envelopes numbered 1, 2, or 3. The first group received a rehabilitation program of 20 min composed of stretching exercises of the elbows, wrists, ankles, knees, and the cervical spine, 20 min of isometric, isotonic, and strengthening exercises for lower and upper extremities designed according to the neurologic status of the patients, 20 min of training for daily living activities, including picking objects of different size, screwing, tying shoelaces, buttoning, and opening doors with keys, 15 min of balance and coordination exercises on balance board or balance training device, and 15 min of a conventional rehabilitation program including gait training, including tandem walk, military walk, walking with obstacles, and changing direction while walking. Five-minute breaks were

given between every exercise set. The second group of patients received 30 min of elbow flexion-extension, supination-pronation, wrist flexion-extension, finger flexion-extension, and hand grip with the Armeo Power arm robot in addition to conventional rehabilitation program. The third group received conventional rehabilitation and Armeo Power arm robot exercises described in the second group, as well as 30 min of recreational activities in line with painting on wood with acrylic colors.

Sociodemographic characteristics of the patients including age, sex, height, weight, body mass index, dominant and affected extremities, education status, and occupation were questioned. The initial symptom and duration of the disease and symptoms, comorbidities, and medications were recorded. Clinical signs including resting tremor, bradykinesia, bradymimia, dementia, postural instability-freezing phenomenon, and sleep disturbances were evaluated. A detailed neurological examination, including muscle strength, ROM, sensation, physiological and pathologic reflexes, tone, and cerebellar tests, were performed.

Disease severity was determined by modified HYS.^[9] It distinguishes five stages of injury and disability, defined as five phases of disease progression, from Stage 1, where there is unilateral damage with no impairment, to Stage 5, where the patient is confined to a wheelchair or bed.

Symptom and signs were evaluated by Unified Parkinson's Disease Rating Scale (UPDRS), a comprehensive 44-item scale in which PD symptoms and signs are rated on an ordinal, ordered scale from 0 (absent) to 4 (severe).^[10] This scale is subdivided into four sections: section 1 for mentation, behavior, and mood; section 2 for activities of daily living; section 3 for motor examination; and section 4 for complications of therapy.

Grip strength was measured using the average of three trials and was measured for each hand with a standard adjustable-handle Jamar dynamometer (Fabrication Enterprises Inc., White plains, NY, USA).^[11] Patients were tested with the forearm in neutral rotation and the elbow flexed at 90°. The wrist was positioned between 0-30° of extension and 0-15° of ulnar deviation. The mean value of three grip strengths was determined by evaluating the dominant hands. Lateral, tip, and three-fingered pinch measurements were also measured with a pinchmeter in the dominant hand, and the mean values were also determined.^[12]

Nine-hole peg test (9-HPT)^[13] was used to evaluate the dexterity of the upper extremity and hand. The patient, sitting at a table, was asked to take nine dowels (9 mm in diameter, 32 mm in length) from the table and place them in nine holes (10 mm in diameter, 15 mm in depth) on the board, 50 mm apart. Completion time was recorded in seconds.

Moreover, the number of supination-pronation of the forearm in 5 sec, repetitive active movement (RAM),^[14] the time to reach all fingers three times [fine finger movement (FFM) test],^[15] and Frenchay arm test^[15] were recorded. Higher numbers meant better coordination for RAM testing. Fine finger movement was assessed by having the patient touch each fingertip sequentially to the thumb of the same hand. The time it took to perform this movement exactly three times was measured in seconds to obtain a score. Higher values indicated abnormal coordination. The Frenchay arm test examines five activities of daily living [lifting and replacing a glass, drawing a line using a ruler, combing hair, lifting and replacing a cylinder (5-cm long), and removing and replacing a spring loaded clothes peg from a dowel] on a scale of 0 to 5, with 5 indicating no paresis. It reflects both hand and arm functions.

Arm, shoulder, and hand problems were assessed by the Disabilities of the Arm, Shoulder, and Hand (DASH)^[16] questionnaire. The main part of the DASH is a 30-item disability/symptom scale regarding the patient's health status over the previous week. The items inquire the degree of difficulty in performing different physical activities due to the arm, shoulder, or hand problem (21 items), the severity of each of the pain symptoms, activity-related pain, tingling, weakness, and stiffness (5 items), and the impact of the problem on social activities, work, sleep, and self-image (4 items). Each item has five response options. The scores for all items are then used to calculate a score ranging from 0 (no disability) to 100 (most severe disability).

The daily living activities and quality of life were questioned using the Parkinson's Disease Questionnaire (PDQ-39),^[17] which assesses 39 parameters in eight groups: mobility, activities of daily living, emotional health, stigma associated with the disease, next step return, cognition, communication, and physical discomfort. Fatigue was assessed with the Fatigue Severity Scale (FSS).^[18] This is a nine-item questionnaire that assesses the

impact of fatigue on daily life. Each item is a statement on fatigue that the subject rates from 1 (completely disagree) to 7 (completely agree).

Patients were evaluated before treatment and after completion of 20 sessions of the rehabilitation program.

Statistical analysis

The sample size in the current study was calculated using G*Power version 3.1.9.7 software (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany) to detect statistical differences with 90% power 5% alpha error, in accordance with Tøstet al.^[19] The minimum sample size was found to be 42 patients.

Data were analyzed using IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as numbers for categorical variables and mean, standard deviation (SD), minimum, and maximum for numeric variables. Median values were used as the descriptive statistics of the continuous variables. The chi-square test was used for comparison of categorical variables. The Wilcoxon signed-rank test was used for comparison of numeric parameters in paired groups, and the Kruskal-Wallis test was applied for comparison of independent groups. Bonferroni correction was performed, and The Mann-Whitney U test was used for post hoc analyses. A p -value <0.05 was considered statistically significant.

RESULTS

The descriptive characteristics of participants were presented in Table 1. The three groups were similar in terms of age, sex, education, body mass index, comorbidity, affected extremity, and disease duration.

When the groups were evaluated before treatment, statistically significant differences were found between the groups in the parameters of UPDRS-motor system examination ($p=0.040$), lateral grip ($p=0.021$), palmar grip ($p=0.015$), 9-HPT ($p=0.024$), RAM test ($p<0.001$) and PDQ-39 stigma subscale ($p=0.005$). However, no significant difference was found between the groups in the subgroups of UPDRS-mentation, behavior, and mood, UPDRS-daily living activities, dominant hand grip, fingertip grip, FFM test, FSS, and PDQ-39, except for the stigma subscale (Table 2).

In the pairwise comparison of the pretreatment groups (Table 2), a significant difference was found between the first and third groups in the UPDRS-motor system examination before and after treatment. However, while there was no significant difference at the beginning, a significant difference was also found between the first and second groups after treatment. In the lateral and palmar grip test, a significant difference was found between the first and second groups before treatment, but no significant difference was found after treatment. In 9-HPT, a significant difference was observed between the second and third groups (Table 2), but after treatment, a significant difference was observed between the first and second groups and between the first and third groups (Table 4). In the RAM test, a significant difference was observed between the second and third groups before treatment (Table 2), but no significant difference was observed between the groups after treatment (Table 4). In the PDQ-39 stigma subscale, a significant difference was observed between the first and second groups before and after treatment (Tables 2, 4).

After the rehabilitation program, all groups had statistically significant increase in dominant hand grip strength assessed by the Jamar hand dynamometer and fingertip, lateral, and palmar grip strength by a pinchmeter. Pre- and posttreatment measurements are shown in Table 3.

There was statistically significant improvement in dominant hand grip strength in the second and third groups compared to the first group. However, there was no significant difference between the second and third groups (Table 4). The fingertip grip strength more significantly improved in the third group compared to the first group. However, there were not significant differences between the first and second groups and the second and third groups (Table 4). Lateral and palmar grip strengths did not differ significantly between the groups. Intergroup comparisons of grip strength test are presented in Table 4. The pairwise comparisons of improvements in dominant hand grip and fingertip grip strength tests are summarized in Table 4.

In pre- and posttreatment comparison of tests evaluating functionality, 9-HPT, RAM, FFM, DASH, and FSS improved significantly in all groups. The Frenchay arm test scores decreased in the second and third groups and remained unchanged in the first group. Posttreatment changes are presented in Table 3.

TABLE I
Descriptive characteristics

	Group 1					Group 2					Group 3					p*
	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	
Age (year)			67.6±8.6	70	48-75			66.0±7.1	67	54-75			63.6±9.3	67	40-72	0.153
Sex																0.181
Female	9	60				4	26.67				7	46.67				
Male	6	40				11	73.33				8	53.33				
Education (University)																0.293
≤11 years	11	73.33				7	46.67				10	66.67				
>11 years	4	26.67				8	53.33				5	33.33				
Occupation																NC
Housewife	9	60				1	6.67				7	46.67				
Worker	3	20				3	20				1	6.66				
Teacher-officer and other	3	20				11	73.33				7	46.67				
BMI (kg/m ²)			28.0±7.2	25	19.7-48.7			27.4±4.2	26.5	23.1-40.4			27.2±4.1	27.3	20.8-33.5	0.924
Dominant extremity																-
Right	15	100				13	86.67				13	86.67				
Left	-	-				2	13.33				2	13.33				
Affected extremity																0.143
Right	4	26.67				5	33.33				2	13.33				
Left	4	26.67				2	13.33				1	6.67				
Bilateral	7	46.66				8	53.34				12	80				
Comorbid disease	11					10					8					0.507
Disease duration (year)			3.5±2.6	3.0	0.5-8.0			3.5±2.6	3.0	0.2-9.0			4.6±4.5	2.0	0.5-15.0	0.914
Hoehn and Yahr Scale																-
Stage 1	5					2					3					
Stage 1.5	2					5					-					
Stage 2	6					4					11					
Stage 2.5	-					1					-					
Stage 3	2					3					1					

SD: Standard deviation; BMI: Body mass index; * Occupation, dominant extremity, affected extremity, and HYS with comparisons regarding p values were not given since expected numbers of cases were low and the chi-square test and Fisher exact test were not met.

TABLE 2 Intergroup comparison of changes in parameters before the rehabilitation program										
	Group 1			Group 2			Group 3			p†
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	
UPDRS-Mentation, behavior and mood	3.00±1.07	3.00	1.0-5.00	3.33±1.35	3.00	2.00-6.00	4.60±2.10	5.00	1.00-8.00	0.071
UPDRS-Daily living activities	12.27±4.25	14.00	3.00-17.00	14.33±5.63	13.00	00:8.00-27.00	17.87±8.26	20.00	3.00-34.00	0.2
UPDRS-Motor system examination	15.40±3.96	14.00	11.00-22.00	19.27±6.30	20.00	11.00-29.00	21.40±8.89	22.00	5.00-41.00	0.040 *
UPDRS-Treatment complications	1.93±3.53	0.00	0.00-13.00	0.87±1.25	0.00	0.00-4.00	0.60±1.30	0.00	0.00-5.00	0.5
Dominant hand grip (kg)	17.90±5.73	18.00	7.50-25.00	22.53±5.11	24.00	14.00- 30.00	19.53±4.49	20.00	10.00-26.00	0.092
Lateral grip (kg)	6.70±2.22	6.50	2.00-11.50	8.50±2.01	9.00	4.00-11.50	6.50±2.30	5.50	3.00-11.50	0.021*
Fingertip grip (kg)	5.83±1.64	6.00	2.00-8.00	7.27±1.84	7.00	3.00- 10.00	6.13±2.19	5.50	3.00-11.00	0.10
Palmar grip (kg)	6.37±1.60	6.50	2.00-9.00	8.27±2.09	9.00	3.00-11.00	6.70±2.13	7.00	3.00-11.50	0.015*
Nine-Hole Peg test (sec)	36.67±14.28	32.00	22.00-78.00	33.4±10.56	34.00	19.0-58.00	52.60±25.46	47.00	21.00-114.00	0.024*
RAM test	6.40±1.59	6.00	3.00-8.00	7.73±1.67	8.00	5.00-10.00	4.87±1.81	4.00	3.00-9.00	<0.001*
FFM test (sec)	7.33±3.87	6.00	3.00-16.00	6.27±2.28	5.00	4.00-12.00	7.67±2.41	7.00	4.00-13.00	0.2
Frenchay arm test	4.40±0.91	5.00	3.00-5.00	4.13±1.25	5.00	1.00-5.00	3.67±1.05	4.00	2.00-5.00	0.11
DASH	85.93±3.54	85.00	62.00-108.00	82.33±20.15	87.00	43.00-113.00	90.27±29.68	97.00	38.00-146.00	0.6
DASH PDQ-39 General	34.14±12.01	33.30	17.00-66.00	33.71±11.35	37.20	12.10-48.10	46.93±19.77	44.20	21.80-80.00	0.13
PDQ-39 Mobility	20.87±7.25	20.00	11.00-40.00	18.20±9.02	17.00	4.00-37.00	25.00±9.72	28.00	12.00-38.00	0.2
PDQ-39 Daily activities	8.33±4.10	8.00	0.00-18.00	8.27±4.89	8.00	0.00-18.00	12.87±7.78	13.00	2.00-28.00	0.2
PDQ-39 Emotional state	11.73±4.82	11.00	6.00-24.00	11.27±4.32	12.00	4.00-17.00	14.20±4.90	12.00	8.00-24.00	0.2

P1-2=0.38
P1-3=0.03
P2-3=1.00

P1-2=0.042
P1-3=1.00
P2-3=0.069

P1-2=0.013
P1-3=1.00
P2-3=0.123

P1-2=1.00
P1-3=0.088
P2-3=0.040

P1-2=0.1281
P1-3=0.0621
P2-3=0.0015

In intergroup comparisons, 9-HPT dominant hand scores were significantly higher in the second and third groups compared to the first group. The FFM score and Frenchay arm test scores were significantly decreased in the third group compared to the first group. The significantly different parameters in intergroup comparisons (Table 3), namely 9-HPT, FFM test, and Frenchay arm test scores, were further analyzed using pairwise comparisons and are summarized in Table 4.

Intragroup comparison of improvements in UPDRS scores significantly decreased in all groups (Table 3). Intergroup comparison in UPDRS scores were statistically more significantly improved in mental status, behavior, and mood, daily living activities, and motor examination dimensions in the second and third groups compared to the first group (Table 4).

General score, mobility, daily activities, and emotional state dimensions of the PDQ-39 scale significantly decreased in all groups after the treatment. As for stigma, cognition, and communication dimensions, scores of the second and third groups decreased significantly (Table 3). The PDQ-39 general score, daily activities, emotional state, stigma, and communication dimensions decreased in the second and third groups compared to the first group (Tables 4).

DISCUSSION

Parkinson disease is a progressive neurodegenerative disorder affecting approximately seven million people worldwide. It is generally encountered in the geriatric population, and 4% of patients are diagnosed under the age of 50.^[20]

Parkinson disease is characterized by movement disorders leading to functional limitations.^[21] Movement disorders impede with daily living activities and can present as reduction in amplitude and velocity of upper extremity movements, difficulty in sequential movements, and loss of skills in fine movements.^[22] Rehabilitation of patients with PD aims to enhance individual's functional capacity and adaptation to social environment.^[23]

A comprehensive rehabilitation program comprising mobilization, enhancement of daily living activities, cognitive functions, and social reintegration should be implemented in PD. In conventional rehabilitation programs for PD,

TABLE 2
Continued

	Group 1			Group 2			Group 3			p [†]
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	
PDQ-39 Stigma	2.93±2.76	3.00	0.00-8.00	3.73±4.06	3.00	0.00-14.00	7.00±3.36	6.00	3.00-13.00	0.005*
PDQ-39 Social support	1.47±2.50	0.00	0.00-7.00	2.80±3.34	1.00	0.00-9.00	2.67±2.19	2.00	0.00-7.00	0.2
PDQ-39 Cognition	4.73±3.26	5.00	1.00-14.00	4.53±1.46	4.00	1.00-7.00	6.07±4.13	6.00	0.00-14.00	0.6
PDQ-39 Communication	1.67±1.91	1.00	0.00-6.00	3.07±2.94	3.00	0.00-9.00	4.47±3.46	4.00	0.00-11.00	0.060
PDQ-39 Bodily discomfort	1.40±1.64	0.00	0.00-4.00	1.53±1.92	1.00	0.00-6.00	3.00±2.36	3.00	0.00-8.00	0.072
Fatigue severity scale	5.33±0.97	5.50	3.20-7.00	4.87±1.27	5.2	2.60-6.70	5.65±1.24	5.60	3.50-7.00	0.2

TABLE 3
Intragroup changes in parameters after the rehabilitation program

	Group 1			Group 2			Group 3		
	Pretreatment Mean±SD (Median; Min-Max)	Posttreatment Mean±SD (Median; Min-Max)	<i>p</i>	Pretreatment Mean±SD (Median; Min-Max)	Posttreatment Mean±SD (Median; Min-Max)	<i>p</i>	Pretreatment Mean±SD (Median; Min-Max)	Posttreatment Mean±SD (Median; Min-Max)	<i>p</i>
Dominant hand grip (kg)	17.9±5.7 (18; 7.5-25)	20.4±6.6 (20; 10-30)	0.001*	22.5±5.1 (24; 14-30)	27.0±4.8 (28; 18-35)	0.001*	19.5±4.4 (20; 10-26)	24.8±4.5 (26; 16-32)	0.001*
Fingertip grip (kg)	5.8±1.6 (6; 2-8)	6.3±1.7 (7; 2-9)	0.006*	7.2±1.8 (7; 3-10)	8.5±2.5 (8; 4-13.5)	0.001*	6.1±2.1 (5.5; 3-11)	7.3±2.1 (7; 4-12)	0.001*
Lateral grip (kg)	6.7±2.2 (6.5; 2-11.5)	7.5±2.6 (7.5; 2-12.5)	0.001*	8.5±2.0 (9; 4-11.5)	9.8±2.3 (10; 6.5-14)	0.002*	6.5±2.2 (5.5; 3-11.5)	7.9±2.3 (8; 4-12.5)	0.001*
Palmar grip (kg)	6.3±1.5 (6.5; 2-9)	7.4±1.9 (7; 2-10)	0.001*	8.2±2.0 (9; 3-11)	9.4±2.2 (9; 5-13)	0.002*	6.7±2.1 (7; 3-11.5)	8.1±2.1 (8; 5-13)	0.001*
Nine-Hole Peg test (sec)	36.6±14.2 (32; 22-78)	32.4±13.5 (27; 20-74)	0.001*	33.4±10.5 (34; 19-58)	26.8±9.4 (25; 12-48)	0.001*	52.6±25.4 (47; 21-114)	40.2±18.6 (37; 20-90)	0.001*
RAM test	6.4±1.5 (6; 3-8)	7.5±1.8 (8; 4-10)	0.003*	7.7±1.6 (8; 5-10)	9.4±1.8 (9; 7-13)	0.001*	4.8±1.8 (4; 3-9)	6.5±2.2 (6; 3-10)	0.005*
FFM test (sec)	7.3±3.8 (6; 3-16)	5.8±3.1 (5; 3-13)	0.001*	6.2±2.2 (5; 4-12)	4.1±1.4 (4; 2-8)	0.001*	7.6±2.4 (7; 4-13)	5.0±1.8 (5; 2-10)	0.001*
Frenchay Arm Test	4.4±0.9 (5; 3-5)	4.5±0.7 (5; 3-5)	0.157	4.1±1.2 (5; 1-5)	5.0±0 (5; 5-5)	0.016*	3.6±1.0 (4; 2-5)	4.6±0.4 (5; 4-5)	0.004*
DASH	85.9±13.5 (85; 82-108)	72.4±12.1 (70; 51-91)	0.001*	82.3±20.1 (87; 43-113)	61.3±16.2 (58; 37-98)	0.001*	90.2±29.6 (97; 38-146)	71.8±22.2 (80; 36-118)	0.001*
Fatigue Severity Scale	5.3±0.9 (5.5; 3.2-7)	4.6±1.1 (5.0; 2.0-6.6)	0.002*	4.8±1.2 (5.2; 2.6-6.7)	3.6±1.0 (4; 2-5)	0.001*	5.6±1.2 (5.6; 3.5-7)	4.4±1.2 (4.7; 2.4-6.4)	0.001*
UPDRS-Mentation, behavior and mood	3.0±1.0 (3; 1-5)	3.0±1.0 (3; 1-5)	NC	3.3±1.3 (3; 2-6)	2.3±1.7 (2; 0-5)	0.007*	4.6±2.0 (5; 1-8)	4.0±1.9 (3; 1-7)	0.024*
UPDRS-Daily living activities	12.2±4.2 (14; 3-17)	10.4±4.1 (12; 2-15)	0.001*	14.3±5.6 (13; 8-27)	8.6±6.1 (7; 1-23)	0.001*	17.8±8.2 (20; 3-34)	12.5±7.5 (10; 2-30)	0.001*
UPDRS-Motor system examination	15.4±3.9 (14; 11-22)	13.0±3.2 (13; 6-18)	0.002*	19.2±6.2 (20; 11-29)	11.9±5.3 (11; 4-21)	0.001*	21.4±8.8 (22; 5-41)	14.4±7.7 (12; 3-31)	0.001*
UPDRS-Treatment complications	1.9±3.5 (0; 0-13)	1.8±3.3 (0; 0-12)	0.317	0.8±1.2 (0; 0-4)	0.5±1.1 (0; 0-4)	0.025*	0.6±1.2 (0; 0-5)	0.4±1.0 (0; 0-4)	0.157*
PDQ-39 General	34.1±12.0 (33.3; 17-66)	30.0±12.5 (30.7; 9-60)	0.001*	33.7±11.3 (37.2; 12.1-48.1)	21.2±11.0 (17.3; 9.6-41.7)	0.001*	46.9±19.7 (44.2; 21.8-80)	34.7±17.5 (35.2; 10.9-65)	0.001*
PDQ-39 Mobility	20.8±7.2 (20; 11-40)	17.5±7.1 (18; 7-36)	0.001*	18.2±9.0 (17; 4-37)	11.8±8.6 (11; 2-35)	0.001*	25.0±9.7 (28; 12-38)	18.8±9.6 (19; 5-36)	0.001*

TABLE 3
Continued

[illegible]

TABLE 4
Intergroup comparison of changes in parameters after the rehabilitation program

	Group 1				Group 2				Group 3				p#
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	
Dominant hand grip (kg)	2.5±1.5	2	0-5	4.4±2.1	4	0-10	5.3±1.6	6	2-8	0.001*			p1-2=0.011" p1-3<0.001" p2-3=0.150
Fingertip grip (kg)	0.4±0.4	0.5	0-1.5	1.3±1.3	1	0-4.5	1.2±0.7	1	0.5-3.5	0.009*			p1-2=0.050 p1-3=0.002" p2-3=0.512
Lateral grip (kg)	0.8±0.5	1	0-2	1.3±1.1	1	0-4.5	1.4±0.7	1	0.5-2.5	0.095			
Palmar grip (kg)	1.0±0.5	1	0-2	1.1±0.8	1	0-2.5	1.4±0.7	1.5	0-3	0.293			
Nine-Hole Peg test (sec)	4.2±2.4	4	2-12	6.6±3.3	6	1-14	12.4±8.0	11	1-28	0.001*			p1-2=0.009" p1-3=0.001" p2-3=0.027
RAM test	1.1±0.9	1	0-3	1.6±0.8	2	0-3	1.6±1.4	2	0-4	0.175			
FFM test (sec)	1.5±0.9	1	0-4	2.1±1.5	2	0-5	2.6±1.1	3	1-5	0.041*			p1-2=0.250 p1-3=0.011" p2-3=0.267
Frenchay Arm test	0.13±0.35	0	0-1	0.86±1.24	0	0-4	1.00±0.84	1	0-2	0.010*			p1-2=0.098 p1-3=0.006" p2-3=0.412
DASH	13.4±11.7	11	1-49	21.0±16.7	13	5-56	18.4±12.0	15	2-43	0.370			
Fatigue Severity Scale	0.71±0.67	0.6	0-2.6	1.2±0.9	0.9	0.2-3.3	1.2±0.7	0.9	0.5-3.0	0.119			
UPDRS-Mentation, behavior and mood	-	-	-	1.0±1.0	1	0-3	0.6±0.9	0	0-3	0.002*			p1-2=0.001" p1-3=0.007" p2-3=0.250
UPDRS-Daily living activities	1.8±1.2	2	0-5	5.6±3.1	5	1-11	5.3±2.3	6	1-10	<0.001*			p1-2<0.001" p1-3<0.001" p2-3=0.818
UPDRS-Motor system examination	2.3±1.8	2	0-6	7.3±3.9	7	2-15	7.0±3.2	7	2-12	<0.001*			p1-2<0.001" p1-3<0.001" p2-3=0.934
UPDRS-Treatment complications	0.06±0.25	0	0-1	0.33±0.48	0	0-1	0.13±0.35	0	0-1	0.145			
PDQ-39 General	4.1±2.6	3.3	1.3-11.5	12.5±9.2	9	1.2-32	12.1±6.5	9.8	2.6-29.5	<0.001*			p1-2=0.003" p1-3<0.001" p2-3=0.683

TABLE 4
Continued

	Group 1			Group 2			Group 3			p#
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	
PDQ-39 Mobility	3.3±2.4	2	1-11	6.4±5.0	6	1-19	6.2±4.7	5	2-20	0.038* p1-2=0.045 p1-3=0.021 p2-3=1.000
PDQ-39 Daily activities	1.6±1.4	2	0-6	4.6±3.9	4	0-17	4.6±4.4	4	4-15	0.006* p1-2=0.003 [“] p1-3=0.009 [“] p2-3=0.744
PDQ-39 Emotional state	0.8±1.0	0	0-3	3.6±4.0	2	1-14	3.8±3.0	3	0-11	0.004* p1-2=0.015 [“] p1-3=0.001 [“] p2-3=0.713
PDQ-39 Stigma	-	-	-	1.3±1.9	0	0-15	1.9±2.3	1	0-8	0.003* p1-2=0.003 [“] p1-3=0.148 p2-3=0.412
PDQ-39 Social support	-	-	-	0.8±1.5	0	1-5	0.3±0.9	0	1-3	0.123 p1-2=0.005 [“] p1-3=0.010 [“] p2-3=0.806
PDQ-39 Cognition	0.2±0.5	0	0-2	1.6±1.5	1	0-5	1.1±1.8	1	2-4	0.013*
PDQ-39 Communication	0.06±0.25	0	0-1	1.3±1.7	1	0-5	1.1±1.5	0	0-5	0.014*
PDQ-39 Bodily discomfort	0.2±0.7	0	0-3	0.5±0.9	0	0-3	1.0±1.8	0	0-7	0.080

SD: Standard deviation; RAM: Repetitive active movement; FFM: Fine finger movement, DASH: Disabilities of the Arm, Shoulder and Hand; UPDRS: Unified Parkinson's Disease Rating Scale; PDQ: Parkinson's disease questionnaire; * p<0.05; ** The Kruskal-Wallis test was used for comparisons. The values before and after treatment is not changed; # The Mann-Whitney U test was used for comparisons. A p-value of 0.016 was accepted as the border according to the Bonferroni correction. The p value was specified using group numbers along with the p value to which the paired encounter belonged. p<0.016.

exercises to maintain muscle length, increase muscle strength, and prevent joint limitations are mainly included. Moreover, programs comprise exercises to increase aerobic capacity, as well as respiratory, gait, balance, and coordination, and they facilitate daily living activities such as eating and dressing.^[1]

In neurorehabilitation clinics, robotic rehabilitation is frequently used in addition to conventional rehabilitation programs. This treatment modality provides long-term and similar-intensity exercises to patients when utilized correctly.^[24] Another benefit of robotic rehabilitation is creating a more entertaining exercise medium by means of virtual reality games and increasing patients' participation.^[25]

In this study, we aimed to investigate the effect of robotic rehabilitation and recreational activities on daily living activities, functional parameters, and mental status when added to conventional rehabilitation programs in patients with PD.

In a study evaluating the effect of a single 15 min exercise session with therapeutic putty on manual dexterity, improvements in dominant hand grip strength determined by Jamar dynamometer and lateral, finger, and palmar pinch strength measured by a pinchmeter were noted in patients with PD.^[19] In the present study, patients received 20 sessions of conventional rehabilitation program lasting 40 min, which comprised daily living activities, including gripping, key opening with supination and pronation, door handle opening, buttoning, tying shoelaces, as well as hand exercises with putty, and resisted exercises. Similar to the results of a study by Mateos-Toset et al.,^[19] we obtained a significant increase in hand grip, finger, lateral, and palmar pinch strengths in all patients. While there was a significant difference between the first and second groups in palmar and lateral grip tests before treatment, no significant difference was found after treatment. While hand grip increased more significantly in the second and third group, palmar and lateral grip increased more significantly in the second group compared to the first group. Finger grip increased more significantly in the third group compared to the first group. In our study, hand grip strength improved both in robot-assisted training and the recreational activity group, but fingertip, lateral and palmar grip results were similar between groups. We believe that the lack of a significant difference between groups in fine hand movements is due to the small number of patients.

In patients with PD, difficulty to initiate motor movements and muscle weakness occurs due to reduced stimulatory effect of the motor cortex as a consequence of dopamine deficiency. In the present study, we found that repetitive, planned, and careful movements for daily living activities increase motor performance and muscle strength. Similar to our results, Mateos-Toset et al.^[19] reported that a single session of a short-term exercise program provided an increase in manual dexterity and muscle strength.

The first study investigating the results of robotic-assisted arm training in PD is a pilot study published in 2014 as a short report. In this study by Picelli et al.,^[26] 10 patients with an HYS of 2.5 and 3 were trained with Bi-Manu Track arm robot (Reha-Stim, Berlin, Germany) for two weeks, 45 min daily. In posttreatment assessments, significant improvements in 9-HPT and Fugl-Meyer tests were reported, whereas only the improvement in 9-HPT was maintained two weeks after the completion of treatment. Since their study was planned as a pilot study, the patient number was lower than ours and the treatment duration was also shorter. In our study, we found a significant improvement in 9-HPT with the addition of the Armeo Power arm robot to conventional rehabilitation program. While Picelli et al.^[26] did not report improvement in UPDRS subscales with robotic rehabilitation, we detected a significant increase in UPDRS subscales of mentation, behavior and mood, daily living activities, and motor examination with addition of robotic rehabilitation to conventional rehabilitation compared to conventional rehabilitation only. In the present study, the addition of Armeo Power arm robot to the rehabilitation program provided visual and sensory feedback and repetitive task-oriented movements as an addition to the study by Picelli et al.^[26] Patients with PD require more somatosensory information to make up for deficiencies in motor planning.^[27] Repetition of task-oriented rhythmic movements and reinforcement with somatosensory stimuli facilitates motor learning by compensating for the lack of excitability in the supplementary motor area and the basal ganglia.^[28] Therefore, we detected significant improvements in upper extremity functions, manual dexterity, daily living activities, motor performance, and muscle strength in groups whom arm robot was added to conventional rehabilitation program. Another study on arm robots in PD patients was the study conducted by Raciti et al.^[29] in 2022. In this study, a total of 30 PD patients with an HYS between 2 and 3 were treated

with the Armeo Power arm robot and conventional treatment in two groups, six days a week, and 45 min per day for eight weeks. The 9-HPT and the UPDRS motor section scores were evaluated before and after treatment. While improvement was observed in both groups after treatment, a more significant improvement was observed in the group treated with the Armeo Power arm robot. Similarly, in our study, a significant improvement was found in the groups with the addition of the arm robot in the 9-HPT and UPDRS motor section compared to conventional treatment alone.

In a study by Herz et al.,^[30] investigating the effect of the three sessions per week for four weeks using the Nintendo Wii game console (Nintendo Co., Ltd., Kyoto, Japan) comprising 1 h of tennis, boxing, or bowling games per session for patients with PD, they reported significant improvements in overall PDQ-39 score and its subscales of daily living activities, emotional status, stigma, cognition, communication, and bodily discomfort, as well as motor subscale of the UDPRS and the 9-HPT score. Similarly, we assessed patients with PDQ-39, UPDRS, and 9-HPT tests. We observed significant improvements in PDQ-39 general score, mobility, daily living activities, and emotional state scores in the conventional rehabilitation group. The addition of robot-assisted exercises to the conventional rehabilitation program lead to significant improvement in all scores except for the bodily discomfort and stigma scores. In the present study, we detected significant enhancement in UPDRS mentation, behavior, mood, and complication subscales, similar to the study by Herz et al.^[30] However, in the group that underwent robotic rehabilitation, we found significant improvement in all UPDRS subscales. In the current study, we also found a significant improvement in 9-HPT after treatment, similar to the results by Herz et al.^[30] Nonetheless, Herz et al.^[30] remarked that the improvements were not maintained four weeks after completion of the rehabilitation program. However, our study lacks long-term evaluation after rehabilitation.

We found that the arm robot was more effective in improving mental status, mood, daily living activities, upper extremity functions, motor performance, hand coordination, and skills due to providing rhythmical and fluent repetitive motor movements.

In our rehabilitation center, we have a hall where patients perform various recreational activities to

the accompaniment of an educator of fine arts with 10 years of experience in a public education center, in addition to conventional rehabilitation programs and robotic arm therapy. In the present study, addition of recreational activities to the conventional program and robot-assisted exercise groups resulted in significant enhancements in grip strength, FFM, and the Frenchay arm test. We believe that the significant increase in fine skills in patients with PD was emerged by performing less automatic and more conscious planning and implementation of motor movements from shoulder to fingers, as in the study of Ghilardi et al.^[31] It has been observed that rehabilitation programs putting emphasis on occupational and daily living activities enhance fine hand skills.

This study had some limitations. In our study, since a long-term rehabilitation program was scheduled and patients were hospitalized during rehabilitation, we included only the patients accepting inpatient rehabilitation. The main limitation of the study was that some patients could not be enrolled since they did not accept hospitalization, leading to low number of patients recruited. Another limitation was the lack of an occupational therapist and ergotherapist in our center. Recreational activities were carried out under the supervision of a craft educator.

In conclusion, the addition of an arm robot to a conventional rehabilitation program provided enhancements in mentation, behavior, mood, daily activities, and motor subscales of UPDRS, PDQ-39 general score and daily living activities, emotional state, and communication subscales, dominant hand grip strength test, and 9-HPT. Furthermore, significant improvements were observed in finger pinch strength, FFM, and the Frenchay arm test. The studies in the literature on the use of robotic rehabilitation in upper extremity rehabilitation in PD are insufficient. According to our results, we believe that the implementation of an arm robot along with conventional rehabilitation program has resulted in positive effects on daily living activities, upper extremity functions, muscle strength, mental and emotional state, while addition of recreational activities lead to improvement of fine hand skills. The present results advocate robot-assisted therapy in PD. However, further comparative studies evaluating long-term effectiveness with broad participation are required.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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