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Evaluation of the functional status of the "unaffected" hand in hemiplegic patients

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Abstract

Objectives: To evaluate the functional status of the unaffected hand in hemiplegic patients and its relationships with activities of daily living. *Methods:* This cross-sectional study included 30 right, 30 left hemiplegic patients with ischemic cerebrovascular accident history in last year, and 30 healthy volunteers. All participants were right-hand dominant. Data on age, gender, height, weight, comorbidities, duration of stroke, Brunnstrom recovery stages were recorded. Handgrip strength (with Jamar-type dynamometer), pinch strengths (with pinch-meter), and hand dexterity [with Nine Hole Peg Test (NHPT)] were evaluated in unaffected hand in patient groups and in both hands in control group. Lawton Instrumental Activities of Daily Living Scale (Lawton-IADL) and Functional Independence Measure (FIM) were applied to patient groups. *Results:* Hand grip and pinch strengths were lower, NHPT duration was longer in right ($p=0.004$, $p=0.03$, $p<0.001$) and left ($p=0.03$, $p=0.02$, $p=0.002$) hemiplegia groups compared to control group. Hand grip and pinch strengths were positively, NHPT duration was negatively correlated with FIM self-care performance ($r:0.47$ $p<0.00$, $r:0.38$ $p=0.003$, $r:-0.40$ $p=0.002$), and Lawton-IADL scores ($r:0.48$ $p<0.001$, $r:0.42$ $p=0.001$, $r:-0.56$ $p<0.001$).

Conclusion: Ipsilesional hand, which is considered unaffected, functions are impaired in hemiplegic patients. This functional impairment is associated with greater dependence on activities of daily living.

Keywords: Hemiplegia, upper extremity, hand, functional status, activities of daily living

INTRODUCTION

Stroke is one of the leading causes of death and permanent acquired disability worldwide.[1,2] Although there have been significant advances in the treatment of acute stroke, most patients experience disabilities that result in loss of functional independence and quality of life.[2,3] Basic and instrumental activities of daily living, which include activities that are important for living independently at home and in the community, can be restricted after stroke.[4] While basic activities of daily living represent activities required for self-care (bathing, dressing, feeding, etc.), instrumental activities of daily living represent activities that allow independence in social life.[5,6] In this respect, instrumental activities of daily living are more complex than basic activities of daily living and require more complex interactions with the environment.[4,6] Insufficient ability to independently perform instrumental activities in stroke patients may be an early sign of loss of function and independence in basic activities.[6]

About 85% of stroke survivors have hemiparesis affecting the upper extremity of one side.[7] Neurological dysfunction usually occurs in the upper extremity contralateral to the cerebral hemisphere where the stroke occurred.[8] The response to the loss after stroke is usually to rely on the ipsilesional upper extremity to maintain function and independence in daily activities and to learn compensatory ways through the ipsilesional upper extremity.[7,8] Relying on the ipsilesional upper extremity puts the relatively intact circuitry of the contralesional hemisphere responsible for completing the majority of the task.[7]

When evaluating the upper extremities after stroke in clinical practice, the ipsilesional upper extremity is traditionally defined as "unaffected" and is taken as a reference for the hemiplegic side.[8] However, the literature indicates that functional effects may also occur in the upper

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extremity, which is considered "unaffected" after stroke. The literature focuses on several possible mechanisms in the causal explanation of ipsilesional upper extremity dysfunction after ischemic stroke. One of these is interrupted and rebalanced bihemispheric activations and the combined action of each hemisphere in motor control of the upper extremities.[9,10] The other is the impaired function of the non-crossing ipsilesional corticospinal tracts descending from the damaged hemisphere and the assumption that these pathways are important in the control of the movement of the ipsilesional upper extremity.[9,11,12] The other is that ipsilesional movement control is dependent on complex interhemispheric communication between cortical areas (i.e., dorsal premotor cortex, additional motor area), possibly mediated through the corpus callosum, for the interhemispheric transfer of perceptual, sensory, and motor information underlying complex and integrated behaviors.[11,12] On the other hand, stroke initiates a dynamic process of repair and remodeling of the remaining neural circuits, and this process is shaped by behavioral experiences.[7] It has been traditionally known that reorganization of the ipsilesional hemisphere after stroke is important to successful recovery.[13] However, there are studies in the literature reporting that neuronal reorganization and activity changes occur not only in the ipsilesional hemisphere but also in the contralesional hemispheres during recovery.[3,13] These changes, which are aimed at restoring the balance between the corticospinal systems after stroke, may be beneficial in terms of general motor function, even if they cause deficits in the nonlesional system.[14]

Ipsilesional upper extremity involvement is not a new concept in stroke research, but despite supporting evidence, it is still poorly recognized and poorly understood.[8] Assuming that the ipsilesional upper extremity is not affected by stroke may lead to ignoring an important component of functional recovery.[8] Therefore, recognizing the impact of stroke on the ipsilesional upper extremity is important to improve the understanding of more effective rehabilitation practices.[8]

In this context, it is important to evaluate the possible impairments in the functional status of the unaffected hand of patients with stroke and the relationships of these impairments with activities of daily living. The primary aim of our study is to evaluate the functional status of the unaffected hand in hemiplegic patients. The secondary aims are to compare the functional states of the unaffected hand between right and left hemiplegias and to evaluate the relationships between the functional status of the unaffected hand and the recovery stage of the hemiplegic side and activities of daily living.

METHODS

Study design and sampling

This cross-sectional study included 30 right hemiplegic and 30 left hemiplegic patients with a history of ischemic cerebrovascular accident (CVA) in the last year and 30 healthy volunteers as a control group. Patients with a history of CVA in the last month, bilateral hemispheric ischemic lesion, moderate/severe cognitive impairment, aphasia, neglect, and patients/healthy volunteers with severe systemic, inflammatory, degenerative, and neurological diseases that may lead to loss of hand functions, a history of surgery or trauma in the upper extremity in the last three months, and younger than 18 years of age were excluded. All patients and healthy volunteers were right-hand dominant.

Data collection

Participants' data on age, gender, height, weight, comorbidities, duration of the stroke, and affected body half were recorded. In the patient group, the recovery stages for the upper extremity and hand were evaluated according to the Brunnstrom recovery stages.[15] Afterward, the participants' handgrip strengths were evaluated with a Jamar-type hand dynamometer[16], pinch strengths with a pinch meter[17], and hand dexterity with the Nine Hole Peg Test (NHPT).[18] Evaluations were made in the unaffected hand in the patient groups and in both hands in the control group. The Lawton Instrumental Activities of Daily Living Scale (Lawton-IADL)[5] and the Functional Independence Measure (FIM)[19] were applied to the patient groups. Ethics committee approval and informed consent form were obtained for the study.

Outcome parameters

The Brunnstrom Recovery Stages: It is a stroke-specific assessment method in which a set of stereotypical events occurring at each stage of motor recovery are evaluated to classify the level of motor recovery after stroke.[15] Six recovery stages (Stage 1: the stage in which no voluntary movement in the affected extremity, Stage 2: the stage in which basic synergies or some of their components begin to be seen with weak voluntary movement attempts and associated reactions, Stage 3: the stage in which basic synergies or some of their components can be performed voluntarily and joint movements can be observed, and spasticity is most evident, Stage 4 and 5: the stages in which reduced spasticity and non-synergy, combined and complex movement patterns, Stage 6: the stage in which isolated joint movement and coordination in movements) are defined for the upper extremity, the lower extremity, and the hand.[15]

The handgrip and pinch strengths: Handgrip strengths and tip pinch strengths were measured using a Jamar-type hand dynamometer and pinch meter available in our clinic. The measurement of handgrip strengths was made with shoulders in adduction and neutral rotation, elbows in 90 degrees flexion, forearms and wrists in the neutral position.[16] Tip pinch strengths were measured by squeezing the pinch meter between the thumb and forefinger.[17] Participants were asked to take a deep breath and grasp with maximal force while exhaling. The measurements were repeated three times with an interval of five minutes, and the average of the values was taken as the basis for the analyses.[16]

The Nine Hole Peg Test (NHPT): Hand dexterities were evaluated with the NHPT available in our clinic. This test is an assembly consisting of a square platform and storage box.[18] There are nine holes in the square-shaped area and nine cylinders suitable for these holes.[18] The patients are asked to take the nine cylinders one by one from the storage box as quickly as possible, place them into the holes, and place them back in the storage box one by one after all the cylinders have been placed.[18] Meanwhile, the total time is measured in seconds with the chronometer. Less time indicates better hand dexterity.[18]

The Lawton Instrumental Activities of Daily Living Scale (Lawton-IADL): Lawton-IADL scale is a scale consisting of eight questions questioning activities using a phone, food preparation, shopping, housekeeping, laundry, use of public transportation, managing self-medication, and handling finances.[5] Each question is scored as 0 (can not perform or can partially perform) or 1 (can perform).[5] The total score ranges from 0 (low functionality, dependent) to 8 (high functionality, independent).[5] The Turkish validity and reliability study of the scale was conducted by Işık *et al*. in 2020.[20]

The Functional Independence Measure (FIM): FIM is an 18-item scale that evaluates the degree of independence of the individual in basic physical and cognitive activities in daily life.[19] It has two main sections in which physical/motor function (13 questions) and cognitive function (5 questions) are evaluated.[19] The part of physical/motor function consists of 4 sub-sections in which different activities [self-care performance (eating, grooming, bathing, upper dressing, lower dressing, toileting), sphincter control, transfers, locomotion] are evaluated. The part of the cognitive function consists of 2 sub-sections in which communication and social-cognition are evaluated.[19] Each item is scored from 1 to 7, with 'level 1' representing full assistance and 'level 7' being complete independence.[19] The higher the total score, the higher the level of independence.[19] The Turkish adaptation study of the scale was carried out in 2001 by Küçükdeveci *et al*.[21]

Statistical analysis

Statistical analyzes were performed using SPSS (Statistical Package for Social Sciences, SPSS Inc, Chicago Ill, USA) version 20 program. The suitability of numerical variables to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Kolmogorov Smirnov/Shapiro Wilk's tests), homogeneity of variances using Levene's test. In descriptive analyses, continuous variables were expressed as mean and standard deviation, and categorical variables were expressed as numbers and percentages. In the comparison of numerical data between groups, when the parametric test conditions are met, independent groups T-test (comparison between two groups) and one-way analysis of variance (comparison between three groups); in cases where parametric test conditions were not met, Mann-Whitney U test (comparison between two groups) and Kruskal Wallis test (comparison between three groups) were used. The Chi-square test was used for the comparison of categorical data between groups. In examining the relationships between variables, Pearson correlation analysis (two-tailed) was used for the variables that both fit a normal distribution, and the Spearman test (two-tailed) was used for the variables at least one of which was not normally distributed. The statistical significance level was accepted as $p=0.05$.

RESULTS

Baseline characteristics

Right hemiplegia, left hemiplegia and healthy volunteer groups were similar in terms of age, gender, height, weight, and presence of comorbidities (p>0.05). There were 12 patients diagnosed with type 2 diabetes mellitus (DM), 23 hypertension (HT), one asthma, one cardiac arrhythmia, one coronary artery disease (CAD) in the right hemiplegia group; 12 type 2 DM, 21 HT, 2 CAD, one hyperlipidemia, one mitral valve replacement in the left hemiplegia group; 10 type 2 DM, one cardiac arrhythmia, one hypothyroidism, 12 HT, 3 CAD, two chronic obstructive pulmonary diseases in the control group.

There were no statistically significant differences between the right and left hemiplegia groups in terms of duration of stroke diagnosis (p=0.06) and the number of patients in the Brunstrom recovery stage 3 or below for upper extremity and hand (p=0.60, p=0.80).

The baseline characteristics of the study are given in Table 1.

Results on comparisons of outcome parameters

Comparisons between right and left hemiplegia groups

It was observed that there were no statistically significant differences between the right and left hemiplegia groups in terms of NHPT duration, handgrip strength, pinch strength, Lawton-IADL score, FIM total, physical/motor section, and self-care performance sub-section scores (p>0.05).

The comparison results of the outcome parameters between the right and left hemiplegia groups are given in Table 2.

Comparisons between patient groups and control groups

The duration of NHPT was found to be statistically significantly longer in the right and left hemiplegia groups compared to the control group (p<0.001 for the right hemiplegia group, p=0.002 for the left hemiplegia group).

The handgrip strength was found to be statistically significantly lower in the right and left hemiplegia groups compared to the control

Table 1: Baseline characteristics

	Right hemiplegia (n=30)	Left hemiplegia (n=30)	Control (n=30)	p
Age-year*	64.2±8.9 (42-82)	64.2±10.2 (43-82)	67.7±10.4 (43-84)	0.29
Gender-n (%)				
Female	9 (30)	8 (26.7)	11 (36.7)	0.69
Male	21 (70)	22 (73.3)	19 (63.3)	
Height-cm*	167.8±8.7 (150-185)	167.5±7.5 (150-180)	165.5±9.4 (150-185)	0.46
Weight-kg*	72.3±8.4 (60-90)	76.2±12 (57-120)	77.7±12 (60-106)	0.23
Presence of comorbidities-n (%)				
Yes	24 (80)	23 (76.7)	19 (63.3)	0.30
No	6 (20)	7 (23.3)	11 (36.7)	
Duration of stroke-month*	5±2.2 (1-12)	6.3±2.8 (2-12)	-	0.06
Brunnstrom recovery stage-upper extremity-n (%)				
≤Stage 3	17 (56.7)	15 (50)	-	0.60
>Stage 3	13 (43.3)	15 (50)		
Brunnstrom recovery stage-hand-n (%)				
≤Stage 3	16 (53.3)	17 (56.7)	-	0.80
>Stage 3	14 (46.7)	13 (43.3)		

* Data are expressed as "mean±standard deviation (minimum-maximum)".
Statistical significance level p=0.05.

group (p=0.004 for the right hemiplegia group, p=0.03 for the left hemiplegia group).

The pinch strength was found to be statistically significantly lower in the right and left hemiplegia groups compared to the control group (p=0.03 for the right hemiplegia group, p=0.02 for the left hemiplegia group).

The comparison results of the outcome parameters between the patient and control groups are given in Table 3.

Comparison of outcome parameters in the patient groups according to the Brunstrom recovery stages

In the right and left hemiplegia groups, there were no statistically significant differences between patients with the Brunnstrom recovery stage grade 3 and below for upper extremity and hand, and patients with above 3, in terms of NHPT duration (p=0.20 for upper extremity, p=0.81 for hand), handgrip strength (p=0.15 for upper extremity, p=0.12 for hand), and pinch strengths (p=0.10 for upper extremity, 0.21 for hand).

It was observed that the Lawton-IADL score was statistically significantly lower in patients with the upper extremity Brunnstrom recovery stage 3 and below compared to patients with a stage above 3 (p=0.03). There was no statistically significant difference between the patients with the hand Brunnstrom recovery stage 3 and below and the patients with a stage above 3 in terms of Lawton instrumental daily living activities score (p=0.15).

It was observed that FIM total, physical/motor section, and self-care performance sub-section scores were statistically significantly lower in patients with the Brunnstrom recovery stage 3 and below for hand (p=0.002 for the total score, p=0.001 for physical/motor score, p<0.001 for self-care performance score) and for upper extremity (p<0.001 for all scores), compared to patients with the stage above 3.

The comparison of outcome parameters in the patient groups according to the Brunstrom recovery stages is given in Table 4.

Examination of correlations between variables

Correlations between outcome parameters

There were moderate positive significant correlations between hand grip strength with pinch strength (r:0.55 p<0.001), FIM total score (r:0.46 p<0.001), FIM physical/motor score (r:0.49 p<0.001), FIM self-care performance score (r:0.47 p<0.001), and Lawton-IADL score (r:0.48 p<0.001), and low level negative significant correlation with NHPT duration (r:-0.27 p:0.04)

Table 2: The comparison results of the outcome parameters between the right and left hemiplegia groups

	Right hemiplegia (n=30)	Left hemiplegia (n=30)	p
NHPT duration-sec*	38.4±17.9 (20-90)	34.2±18.7 (15-122)	0.35
Hand grip strength-kg*	17.9±7.3 (5-32)	17.9±7.6 (2-30)	0.99
Pinch strength-kg*	10.5±6.6 (3-30)	9.6±4.8 (2.5-23.2)	0.98
Lawton-IADL score*	3.4±2.6 (0-8)	3.8±2.2 (1-8)	0.41
FIM total score*	85.7±28.2 (38-126)	94.2±19.8 (44-126)	0.29
FIM physical/motor score*	56.4±22.7 (21-91)	61.7±17.8 (20-91)	0.32
FIM self-care performance score*	24.8±10.7 (9-42)	26.2±8.3 (11-42)	0.58

* Data are expressed as “mean±standard deviation (minimum-maximum)”.
Abbreviations; NHPT: Nine Hole Peg Test, Lawton-IADL: Lawton Instrumental Activities of Daily Living, FIM: Functional Independence Measure
Statistical significance level p=0.05.

Table 3: The comparison results of the outcome parameters between the patient and control groups

	Right hemiplegia (n=30)	Control (n=30)	p
NHPT duration-sec*	38.4±17.9 (20-90)	23.9±7.4 (15.5-44.2)	**<0.001****
Hand grip strength-kg*	17.9±7.3 (5-32)	32.3±20.8 (4-85)	**0.004****
Pinch strength-kg*	10.5±6.6 (3-30)	13.4±6.3 (4-30)	**0.03****
	Left hemiplegia (n=30)	**Control (n=30)**	**p**
NHPT duration-sec*	34.2±18.7 (15-122)	25.1±6.2 (17-42.9)	**0.002****
Hand grip strength-kg*	17.9±7.6 (2-30)	29.4±20.3 (5-80)	**0.03****
Pinch strength-kg*	9.6±4.8 (2.5-23.2)	13.2±6.2 (4-25)	**0.02****

* Data are expressed as "mean±standard deviation (minimum-maximum)".
Abbreviations; NHPT: Nine Hole Peg Test
**Statistical significance level p=0.05.

There were moderate positive significant correlations between pinch strength with hand grip strength (r:0.55 p<0.001), FIM total score (r:0.38 p=0.002), FIM physical/motor score (r:0.41 p=0.001), FIM self-care performance score (r:0.38 p=0.003), and Lawton-IADL score (r:0.42 p=0.001).

There were moderate negative significant correlations between NHPT duration with FIM total score (r:-0.40 p=0.001), FIM physical/motor score (r:-0.40 p=0.001), FIM self-care performance score (r:-0.40 p=0.002), and Lawton-IADL score (r:-0.56 p<0.001), and low level negative significant correlation with hand grip strength (r:-0.27 p:0.04).

There were excellent positive significant correlations between the Lawton-IADL with FIM total (r:0.81 p<0.001), physical/motor (r:0.82 p<0.001) and self-care performance (r:0.82 p<0.001) scores, between FIM self-care performance with FIM total (r:0.95 p<0.001) and physical/motor scores (r:0.96 p<0.001), between FIM physical/motor with FIM total scores (r:0.99 p<0.001).

The results of examining the correlations between the outcome parameters are given in Table 5.

Correlations in terms of subdomains of the scales

The strongest first three correlations for hand grip strength were correlations with dressing-lower (r:0.52 p<0.001), bathing (r:0.51 p<0.001) and dressing-upper (r: 0.48 p<0.001) in the FIM self-care performance assessment; managing self-medication (r:0.44 p<0.001), handling finances (r:0.44 p<0.001), and housekeeping (r:0.38 p:0.003) in the Lawton-IADL.

The strongest first three correlations for pinch strength were correlations with dressing-lower (r:0.43 p=0.001), bathing (r:0.42 p=0.001) and grooming (r:0.36 p=0.004) in the FIM self-care performance assessment; handling finances (r:0.35 p=0.005), housekeeping (r:0.34 p=0.008), and managing self-medication (r:0.32 p:0.01) in the Lawton-IADL.

The strongest first three correlations for NHPT duration were correlations with grooming (r:-0.49 p<0.001), bathing (r:-0.39 p=0.002), and dressing-lower (r:-0.33 p=0.009) in the FIM self-care performance assessment; handling finances (r:-0.55 p<0.001), laundry (r:-0.47 p<0.001), and housekeeping (r:-0.41 p:0.001) in the Lawton-IADL.

Correlations of the outcome parameters in the right and left hemiplegia groups

Right hemiplegia group

There were negative moderate significant correlations between NHPT duration with FIM total (r:-0.51 p:0.004), FIM physical/motor (r:-0.53, p:0.002), FIM self-care performance

Table 4: The comparison of outcome parameters in the patient groups according to the Brunstrom recovery stages

	Stage 3 and below	Above Stage 3	p
Upper extremity	(n=32)	(n=28)	
NHPT duration-sec*	40.07±22.7 (15-122)	32.03±10.04 (17-54)	0.20
Hand grip strength-kg*	16.61±7.5 (2-30)	19.4±7.2 (7-32)	0.15
Pinch strength-kg*	9±4.9 (2.5-23.2)	11.3±6.4 (3-30)	0.10
Lawton-IADL score*	2.7±2.02 (0-8)	4.6±2.4 (0-8)	**0.003****
FIM total score*	79±22.7 (38-115)	102.4±20.5 (53-126)	**<0.001****
FIM physical/motor score*	49.5±18 (20-80)	70±17.6 (33-91)	**<0.001****
FIM self-care performance score*	21±7.3 (9-34)	30.6±9.3 (12-42)	**<0.001****
Hand	(n=33)	(n=27)	
NHPT duration-sec*	38.8±23 (15-122)	33.2±9.5 (20-54)	0.81
Hand grip strength-kg*	16.6±7.4 (2-30)	19.6±7.2 (7-32)	0.12
Pinch strength-kg*	9.2±5 (2.5-23.2)	11.2±6.5 (3-30)	0.21
Lawton-IADL score*	2.9±2.1 (0-8)	4.4±2.5 (0-8)	0.15
FIM total score*	80.9±24 (38-117)	101±20.7 (53-126)	**0.002****
FIM physical/motor score*	51.1±19.1 (20-82)	68.8±17.8 (33-91)	**0.001****
FIM self-care performance score*	21.3±7.9 (9-36)	30.6±8.9 (12-42)	**<0.001****

*Data are expressed as "mean±standard deviation (minimum-maximum)."
Abbreviations; NHPT: Nine Hole Peg Test, Lawton-IADL: Lawton Instrumental Activities of Daily Living, FIM: Functional Independence Measure
**Statistical significance level p=0.05.

(r:-0.48 p:0.007), and Lawton-IADL scores (r:-0.56 p:0.001).

There were positive moderate significant correlations between pinch strength with FIM total (r:0.42 p:0.02), FIM physical/motor (r:0.47, p:0.008), FIM self-care performance (r:0.45 p:0.01), and Lawton-IADL scores (r:0.41 p:0.02).

There was no significant relationship between handgrip strength with Lawton-IADL and FIM scores (p>0.05).

In the right hemiplegia group, the strongest correlations were observed between NHPT duration with Lawton-IADL laundry (r:-0.55 p:0.002) and FIM self-care performance scores (r:-0.54 p:0.002).

Left hemiplegia group

There was a negative moderate significant correlation between NHPT duration with Lawton-IADL score (r:-0.54 p:0.002). No significant

Table 5: The results of examining the correlations between the outcome parameters

	Handgrip strength	**Pinch strength**	**NHPT duration**	**FIM total score**	**FIM Physical/ motor score**	**FIM Self-care performance score**	**Lawton-IADL score**
Handgrip strength		**r:0.55** p:<0.001**	**r:-0.27* p:0.04**	**r:0.46** p:<0.001**	**r:0.49** p:<0.001**	**r:0.47** p:<0.001**	**r:0.48** p:<0.001**
Pinch strength	**r:0.55** p:<0.001**		r:-0.23 p:0.08	**r:0.38** p:0.002**	**r:0.41** p:0.001**	**r:0.38** p:0.003**	**r:0.42** p:0.001**
NHPT duration	**r:-0.27* p:0.04**	r:-0.23 p:0.08		**r:-0.40** p:0.001**	**r:-0.40** p:0.001**	**r:-0.40** p:0.002**	**r:-0.56** p:<0.001**
FIM total score	**r:0.46** p:<0.001**	**r:0.38** p:0.002**	**r:-0.40** p:0.001**		**r:0.99** p:<0.001**	**r:0.95** p:<0.001**	**r:0.81** p:<0.001**
FIM Physical/ motor score	**r:0.49** p:<0.001**	**r:0.41** p:0.001**	**r:-0.40** p:0.001**	**r:0.99** p:<0.001**		**r:0,96** p:<0.001**	**r:0.82** p:<0.001**
FIM Self-care performance score	**r:0.47** p:<0.001**	**r:0.38** p:0.003**	**r:-0.40** p:0.002**	**r:0.95** p:<0.001**	**r:0,96** p:<0.001**		**r:0.82** p:<0.001**
Lawton-IADL score	**r:0.48** p:<0.001**	**r:0.42** p:0.001**	**r:-0.56 p:<0.001**	**r:0.81** p:<0.001**	**r:0.82** p:<0.001**	**r:0.82** p:<0.001**	

* Statistical significance level of correlation is p=0.05 (2-tailed)
** Statistical significance level of correlation is p=0.01 (2-tailed)
Abbreviations; NHPT: Nine Hole Peg Test, Lawton-IADL: Lawton Instrumental Activities of Daily Living, FIM: Functional Independence Measure

correlation was observed between NHPT duration with FIM scores (p>0.05).

There was a positive moderate significant correlation between pinch strength with Lawton-IADL score (r:0.41 p:0.03). No significant correlation was observed between pinch strength with FIM scores.

There were positive, strong significant correlations between hand grip strength with FIM total (r:0.71 p<0.001), FIM physical/motor (r:0.70, p<0.001), FIM self-care performance (r:0.65 p:0.01), and Lawton-IADL scores (r:0.69 p<0.001).

In the left hemiplegia group, the strongest correlations were observed between handgrip strength with FIM bathing score (r:0.73 p<0.001) and between NHPT duration with Lawton-IADL handling finances score (r:-0.64 p<0.001).

DISCUSSION

In this study, which aimed to evaluate the functional status of the unaffected hand and its relationship with daily living activities in patients who developed hemiplegia after ischemic stroke, it was observed that ipsilesional hand functions, which were considered unaffected, were impaired in both right and left hemiplegic patients compared to healthy individuals. In addition, it was observed that this impairment was associated with impairment in activities of daily living.

Functional status of the upper extremity considered unaffected in hemiplegic patients compared to healthy volunteers

In our study, it was observed that the handgrip, pinch strengths, and hand dexterity, which are the outcome parameters we use to determine the functional state of the hand in the unaffected upper extremity, were significantly lower in hemiplegic patients compared to healthy individuals.

Consistent with our results, it was stated in the literature that after ischemic stroke, deficits in strength and movement patterns could be observed in the ipsilesional upper extremity, and these deficits may affect the functional capacities of patients.[8] There are different studies evaluating the functional status of the ipsilesional upper extremity after stroke with different methods.[8-12,14,22,23] Pellegrino *et al*. reported that there was a loss in the ability to apply isometric forces in the ipsilesional upper extremity after stroke, and this effect was associated with abnormal activity of the proximal muscles, especially during pushing or pulling movements in the lateral directions.[22] In their study, in which they evaluated sensorimotor electroencephalogram, electromyogram, and corticomuscular coherence during rest and isometric contraction in stroke patients, Graziado *et al*. reported that significant changes occurred at both cortical and spinomuscular levels after stroke, and these changes developed in the same degree and in the same direction in both lesional and nonlesional corticospinal systems.[14] Kwon *et al*. reported that the gains in visual-spatial movements and motor skill training in the ipsilesional upper extremity in stroke individuals are less than in healthy individuals.[9] In their study examining the motion kinematics of the ipsilesional upper extremity in moderate and mild strokes, Bustren *et al*. reported that the motion kinematics were impaired in the ipsilesional extremity, the movements were slower and less smooth, the duration of the deceleration phase of the movement was longer, and these impairments were more pronounced in the early stages of the stroke.[11] Subramaniam *et al*. evaluated ipsilesional functional arm extension in chronic stroke patients and stated that there were deteriorations in performance measures (prolonged reaction, movement time, movement onset, and peak times) and decreased performance production ability.[12] In their study, in which they used a comprehensive sensorimotor assessment model with a functional perspective to determine the involvement in the ipsilesional upper extremity in stroke patients, Hsu *et al*. reported that sensory, perception, and motor abilities were affected.[23] Johnson *et al*. reported that gross and fine motor performance disorders were observed in the ipsilateral upper extremity in individuals with chronic stroke.[10]

When the findings obtained from our study and the literature are considered together, we think that the damage caused by the stroke itself and the neuronal reorganization and activity changes in the recovery process after stroke may be the cause of the functional changes in the ipsilateral upper extremity.[9,14]

Involvement of the unaffected upper extremity according to the severity of the involvement of the hemiplegic side

In our study, handgrip strength, pinch strength, and hand dexterity were worse (although not statistically significant) in the patients with Brunnstrom grade 3 and below for the upper extremity and hand compared to the patients with a score above 3, in both the right and left hemiplegia groups.

Similar to our study, Maenza *et al*. reported that functional deficits in the ipsilesional upper extremity were associated with the severity of contralesional involvement.[24] Bustren *et al*. also stated that when motor involvement is more severe, the deterioration in movement kinematics is more pronounced in the ipsilesional extremity.[11] Varghese *et al*. reported that the relationship between ipsilesional motor capacity and contralateral upper extremity involvement was stronger in those with left hemisphere damage than in those with right hemisphere damage. In addition, they stated that when contralesional extremity involvement is more severe, those with left hemisphere injury of the ipsilesional hand are slower than those with right hemisphere injury.[25]

When the results of the studies are taken together, the increase in functional impairments in the ipsilesional upper extremity as the severity of the hemiplegic side is affected suggests that the possible neural mechanisms (ipsilateral corticospinal tracts, interhemispheric connections, etc.) that contribute to the motor control of the ipsilesional upper extremity may be more likely to be affected.

Functional status of the unaffected upper extremity according to the presence of right or left hemiplegia

In our study, it was observed that there was no significant difference between the right and left hemiplegia groups in terms of handgrip and pinch strengths, hand dexterity, and activities of daily living.

There are studies with different results evaluating the effects of the affected hemisphere on the functional state of the ipsilesional upper extremity. Similar to our study, Cunha *et al*. reported that grip and coordination were found to be similar in right and left hemiplegic patients in chronic stroke patients.[26] In addition, they reported that the starting time for objects to be lifted is longer in patients with left brain damage, and they pointed out that the left hemisphere may play the main role in the processing of somatosensory information from objects in the control of objects.[26] In the study of Metrot *et al*., in which they evaluated motor recovery in the ipsilesional upper extremity in subacute stroke patients, it was reported that the hemisphere where the lesion is located has no effect on ipsilateral motor deficits, similar to our study.[27] Unlike these, Maenza *et al*. stated that ipsilesional deficits were more common in patients with left hemisphere lesions.[24] On the contrary, Cunha *et al*., in their study evaluating ipsilesional hand functions in chronic stroke patients, reported that patients with right-brain damage were slower in tasks requiring finger dexterity than those with left-brain damage.[28] The diversity in the findings from the studies suggests that the differences in the results may be due to the differences in the samples and methodologies.

In the literature, we could not find any other study similar to ours that draws attention to functional evaluations when the ipsilesional hand is dominant or non-dominant, and the relationship between these evaluations and activities of daily living. We think that the finding in our study that the functional status and activities of daily living are similar when the ipsilesional hand is dominant and non-dominant supports that the functional status of the ipsilesional hand, which is considered unaffected, and its relationship with activities of daily living are independent of hand dominance.

The relationship between the functional status of the unaffected upper extremity and activities of daily living

In our study, we found that the greater the handgrip, pinch strengths, and hand skills of the unaffected upper extremity, the better the functional status of the patients and the greater the independence in activities of daily living.

In previous studies, it has been shown that there are relations similar to the one we found in our study. Gulde *et al*., in their study evaluating ipsilesional upper extremity kinematics during multilevel activities of daily living, reported that stroke patients had a longer time to complete daily activities with their ipsilesional upper extremities and showed a lower mean peak velocity compared to healthy subjects.[29] They suggested that the important factor in this situation might be the increase in the immobility time of the hand.[29] Cho *et al*. reported that the basal manual functional state of the ipsilesional upper extremity was correlated with the functional results of the patients and was an important predictor of functional recovery after a 1-month follow-up.[30]

Jayasinghe *et al*. reported that functional independence was more related to the grip strength of the ipsilesional upper extremity in patients with left hemisphere damage and to the grip strength of the contralesional extremity in patients with right hemisphere damage, while ipsilesional upper extremity kinematics was associated with functional independence only in the left hemisphere injury group.[31] As a striking result, they reported that the significant effects of the functional state of the ipsilesional upper extremity on functional independence suggest that activities of daily living may be based mainly on the manipulative abilities of the ipsilesional, that is, less affected upper extremity, rather than the contralesional upper extremity.[31] In our study, pinch strength and dexterity of the left hand were found to be associated with basic and instrumental activities of daily living in the right hemiplegia group, while handgrip strength was found to be unrelated to both. In the left hemiplegia group, pinch strength and dexterity of the right hand were found to be associated only with instrumental activities of daily living, while handgrip strength was strongly associated with both basic and instrumental activities of daily living. All participants in the study were right-hand dominant. In this context, we think that when the ipsilesional upper extremity is the dominant side, it can be said that the influence in basic activities of daily living in relation to the handgrip strength is more remarkable when it is the non-dominant side, the influence in the instrumental activities of daily living in relation to pinch strength and hand dexterity.

The lower FIM and Lawton-IADL scores in hemiplegia groups compared to the control group and lower Lawton-IADL scores in those with lower FIM scores were the findings we expected. On the other hand, the reason why we wanted to examine the relationship between the functional evaluations of the unaffected upper extremity and Lawton-IADL as well as the FIM scores, is that we thought that the functional status of the unaffected upper extremity might affect the instrumental activities of daily living more than the basic activities of daily living since the instrumental activities of daily living are more complex than basic activities of daily living. The findings of our study support this idea.

Contribution of the study to the literature

In the literature, there are studies evaluating the relationship between the functional state of the ipsilesional upper extremity and basic activities of daily living.[9,29,30] As far as we know, our study is the first study in the literature to evaluate the relationship between the functional status of the ipsilesional upper extremity and instrumental activities of daily living. As another important contribution, while most of the previous studies on this subject in the literature evaluated right and left hemiplegia patients under one group and compared their upper extremity functional status with healthy volunteers, right and left hemiplegias were evaluated in separate groups in our study. This allowed us to make comparisons of functional status and to evaluate the relationships with activities of daily living in cases where the ipsilesional upper extremity is dominant and non-dominant side. Another contribution is that it draws attention to the importance of interventions for the ipsilesional upper extremity in upper extremity rehabilitation applications in stroke patients in terms of its contribution to practical practice.

Limitations of the study

There are some limitations of our study. The first of these is that although patients with bilateral hemispheric lesions were excluded in ischemic stroke patients, the analyzes were not deepened according to the location of the lesions. This evaluation was not made because it is thought that the number of available samples will be relatively low for the subgroup analyses to be made in this way. The second limitation is that all participants were right-hand dominant. This may limit the generalizability of the results for left-hand dominant individuals.

Suggestions for future studies

We think that future studies that include larger samples, including left-hand dominant individuals, and deepen the evaluations according to the location of ischemic lesions, may provide more comprehensive information about the functional status of the ipsilesional upper extremity and its relations with daily living activities. Future studies evaluating the functional status of the ipsilesional upper extremity in patients with lower brainstem involvement and a longer period after stroke may better reflect the relationship between this functional status and instrumental activities of daily living. In addition, the use of advanced imaging techniques, such as functional magnetic resonance imaging, in studies planned as mentioned may have important benefits in terms of contributing to the literature and clinical practice.

Importance of the study in terms of clinical practice

When the results of our study and other studies on the subject are considered together, we conclude that, contrary to traditional belief, it may be misleading to describe the ipsilesional extremity as "unaffected" in stroke patients. In this context, we think that care should be taken when using the ipsilesional upper extremity as a reference for the hemiplegic side in clinical evaluations.[8,9,11]

In our study, it was observed that hand dexterity and grip strengths in the ipsilesional upper extremity were lower in the hemiplegia groups than in the control group, and these functional impairments were associated with worse evaluations of basic and instrumental activities of daily living. This perspective makes us think that rehabilitation approaches designed to improve the hand dexterity and grip strengths of the ipsilesional upper extremity in stroke patients will both improve the functions of the ipsilesional upper extremity and improve daily living activities. We think that the results obtained from the evaluation methods of the functional status of the ipsilesional upper extremity in stroke patients can be evaluated by comparing the results of the relevant methods with the literature data reporting the values observed in healthy adults. In addition, we think that the improvement in the functional status of the ipsilesional upper extremity and related activities of daily living can be followed by repeating these evaluations at baseline and intermittently during the rehabilitation period.

In terms of rehabilitation practices, these findings support the need for clinicians to evaluate and treat functional involvement of the ipsilesional upper extremity in order to effectively manage upper extremity rehabilitation after stroke.[8] Although the contralateral side remains the primary focus in upper extremity rehabilitation, bilateral interventions that address deficiencies in both the contralateral upper extremity and the ipsilesional upper extremity may facilitate activities of daily living and help community-dwelling chronic stroke survivors maintain functionally independent lives.[8,12] Current rehabilitation approaches generally have focused on the ipsilesional upper extremity function as a compensatory technique. On the other hand, the fact that functional impairments in the ipsilesional upper extremity and the relationship of these impairments with activities of daily living were shown in our study shows that rehabilitation techniques for the ipsilesional upper extremity should not be limited to compensatory techniques, but should also include the treatment of functional impairments (such as exercises to increase grip strength and improve hand dexterity) in the ipsilesional upper extremity. We think that including rehabilitation approaches for ipsilesional upper extremity as soon as patients are included in the rehabilitation process can provide better functional results and quality of life.

In conclusion, it was observed that hand functions were impaired in the ipsilesional upper extremity, which was considered unaffected, in patients who developed both right and left hemiplegia after ischemic stroke. This functional impairment was associated with greater dependence on activities of daily living. When the ipsilesional upper extremity is the dominant side, the influence in basic activities of daily living in relation to the handgrip strength was more remarkable; when it is the non-dominant side, the influence in the instrumental activities of daily living in relation to pinch strength and hand dexterity.

DISCLOSURE

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