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Impact of a Rehabilitation Program on the Change in Components of Body Mass of the Upper and Lower Limbs in People After Ischemic Stroke

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Background: The aim of this study was to evaluate the effects of rehabilitation in terms of changes in the body mass composition in the upper and lower limbs depending on the length of time after stroke and the age of the patient.

Material/Methods: Eighty-two patients after ischemic stroke were tested 3 times: on admission, after 5 weeks, and 3 months after leaving the hospital (follow-up). During each examination, a segmental analysis of the components of the body mass of the upper limbs and lower limbs was performed, depending on the side of paresis.

Results: Patients between 7 and 12 months after stroke with right-sided paresis had a reduction of fat ($P=0.027$) and an increase in muscle tissue in the lower ($P=0.030$) and upper limbs with paresis ($P=0.037$), as well as in the healthy upper limb ($P=0.034$) after rehabilitation. Only in the youngest age group (25-44 years) and in patients with left-sided paresis was there a decrease of adipose tissue in the healthy upper ($P=0.012$) and paresis limbs ($P=0.032$) and an increase in the muscle tissue mass in the right upper limb ($P=0.010$) after rehabilitation.

Conclusions: The rehabilitation program had a significant impact on the change in the composition of body mass in upper and lower limbs in people with right-sided paresis, particularly 7 to 12 months after stroke and in the youngest age group (25-44 years). These results may be useful in planning a rehabilitation program for stroke patients to consider the patient's dominant hand and neglect.

Keywords: **Adipose Tissue • Body Composition • Follow-Up Studies • Ischemic Stroke • Neoplasms, Muscle Tissue • Paresis • Rehabilitation**

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Background

Stroke is currently an increasingly common cause of permanent disability worldwide. A stroke incident leads to permanent disability, with people often requiring assistance from third parties after stroke, and can even lead to death [1,2].

Worldwide, approximately 17 million people have a stroke each year, and in Poland the incidence of ischemic stroke is estimated at around 90 000 cases [3]. Stroke is the second most common cause of death in the world after ischemic heart disease and is often associated with various long-term physical and neuropsychological consequences [4-6]. Despite the decrease in mortality due to stroke observed in recent years, the global burden of stroke is increasing. A more comprehensive approach to primary stroke prevention is needed as is the timely start of comprehensive rehabilitation [7,8].

The literature points out that the body mass composition of patients after stroke should also be considered in the rehabilitation process [9,10]. Early rehabilitation allows for the return of lost functions by, among other things, faster muscle mass growth [11]. After a stroke, there is a reduction in muscle mass, loss of fat-free mass and bone mineral content, and increased adipose tissue (fat) [12,13]. This results in a reduction in functional efficiency in patients after stroke. It is also interesting that few researchers note in their reports that stroke and hemiparesis are associated with changes in the body composition of the limbs, especially bone and fat-free mass. They show that a stroke is likely to cause an increase in the fat mass of the trunk, but not in the limbs [14].

Studies indicate that the greatest progress in the recovery of functional fitness can be expected in the early period after stroke, when patients often show a significant improvement in neuromotor functions [15,16], this process slows down later, and patients tend to present persistent patterns [17, 18]. Nevertheless, numerous studies have reported that inter-neuronal connections can be continuously remodelled by physical activity, and that brain plasticity can be increased through various types of training [19-22]. Moreover, age has also been reported to influence the achievement of positive brain plasticity results during motor training [23].

There are reports in the literature on the effects of rehabilitation depending on the time after stroke [24,25] or age [26-29], and to the best of our knowledge, there are no studies on the effects of rehabilitation in terms of changes in the body mass composition depending on the length of time after stroke and patient age. Therefore, the aim of the study was to evaluate the effects of rehabilitation in terms of changes in the body mass composition in the upper and lower limbs depending on time after stroke and age of the patients.

Material and Methods

Type of Study

This was a prospective observational study. The study was conducted in accordance with the Helsinki Declaration, and it was approved by the local bioethics commission (approval no. 2015/10/03). Written consent was obtained from all participants in the study.

Participants and Inclusion and Exclusion Criteria

During the research period, 403 patients after stroke were in the Rehabilitation Clinic's Early Neurological Rehabilitation Unit. Prior to the study, a sample size was calculated from the 403 patients who were in the clinic during this period. With a 95% confidence interval, a significance level of 0.05, and a maximum error of 10%, it was calculated that the minimum sample size should be 78. Considering the inclusion and exclusion criteria, the study included 82 patients after ischemic stroke staying in the Rehabilitation Clinic's Early Neurological Rehabilitation Unit.

The inclusion criteria for the entire study group were as follows: diagnosis of ischemic stroke, first complete stroke, the ability to stand without assistance, walking independently without the help of other people (including a doctor, nurse, physiotherapist) or with a little ankle-foot orthosis type support, no impairment of higher mental functions, right-handedness, completion of a 5-week inpatient rehabilitation program, informed consent to participate in the study, and age ≥ 25 years.

The inclusion criteria in examination III (follow-up) were as follows: physical activity measured by the self-report physical activity questionnaire (SPAQ) at a low-intensity level, not using additional rehabilitation between examination II and examination III, and appearing for a follow-up visit 3 months after discharge from the hospital.

The exclusion criteria for the whole study group were as follows: lack of consent of the patient to participate in the study, incomplete stroke (eg, transient ischemic attack), hemorrhagic stroke, second or subsequent stroke, inability to stand independently (balance disorders and dizziness), ischemic lesion located in the cerebellum and brainstem, electronic implants, epilepsy, pregnancy, menstruation in women, and leg injuries after stroke.

Measurements

Patients were divided into 4 age groups: young age was from 25 to 44 years, middle age was from 44 to 60 years, elderly age was 60 to 75 years, senile age was ≥ 75 years [30]. Considering

Table 1. Characteristics of the study group.

Variable		N	%
Place of residence	Urban area	42	52.5%
	Rural area	38	47.5%
Sex	Female	36	45.1%
	Male	44	54.9%
Age	25-44 years	11	13.7%
	45-60 years	28	35.1%
	61-75 years	30	37.5%
	>75 years	11	13.7%
Time from stroke	2-3 months	11	13.7%
	4-6 months	8	10.0%
	7-12 months	15	18.7%
	>12 months	45	54.9%
Side of paresis	Left	40	50.0%
	Right	40	50.0%
Education	Primary	7	8.8%
	Secondary	31	38.7%
	Vocational	29	36.25%
	Higher	13	16.2%

the time since stroke in the study group, there were patients who were in the early and late periods after stroke. In assessing the effects of rehabilitation on changes in the body mass of the upper and lower limbs depending on the time after stroke, the group of patients was divided according to time after stroke as follows: 2 to 3 months, 4 to 6 months, 7 to 12 months, and >12 months [31]. Patients were also divided by sex (Table 1).

The body mass composition of patients was evaluated with the 780 MA Tanita MC analyzer, which is based on the measurement of electrical bioimpedance [32,33]. The analyzer is able to carry out a segmental body assessment, including of adipose tissue (fat) and muscle mass, which is divided into right and left arm, right and left leg, and trunk. The body height was measured to within 0.1 cm using the portable PORTSTAND 210. Measurements were made under standard conditions. Patients wore underwear and no shoes and were instructed to assume an upright posture. The analyzer is approved for medical use and meets the Non-Automatic Weighing Instrument Class III standards for scales used for medical measurements. The analyzer has European Union CE0122 certification. With regard to medical devices, it meets the requirements of the Medical Device Directive 93/42/EEC.

Procedure

All patients participated in a 5-week rehabilitation program that lasted 5 days a week, from Monday to Friday. The rehabilitation

program was based on neurodevelopmental methods, gait and upper limb training, as well as exercises on equipment using biological feedback and static and dynamic parapodium. The tests were performed 3 times: the first test (examination I) was performed at admission to the clinic prior to rehabilitation. A second test (examination II) was performed at discharge after 5 weeks of hospital rehabilitation. The third test (examination III) was performed as a follow-up 3 months after leaving the clinic during a follow-up visit.

After examination II, rehabilitation activities were limited to the recommendations that the patients and family members received upon discharge from the hospital from the therapeutic team; the patients did not use additional rehabilitation in the period between examinations II and III. An additional recommendation was to maintain physical activity at least at a low-intensity level, including basic everyday activities, light housework, light gardening, grocery shopping, and leisurely walks (according to the SPAQ) [34,35].

Inclusion criteria were developed for all 3 examinations (examination I, examination II, examination III), and additionally (and separately) for examination III (follow-up), with a 3-month interval between measurement II and measurement III.

Table 2. The effect of rehabilitation on the amount of fat in age groups 25 to 44 and 45 to 60 years.

Age	Side of paresis	Exam	N	FAT			FAT right lower limb			FAT left lower limb			FAT right arm			FAT left arm		
				Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P
After rehabilitation																		
25-44 years	Left	Exam I	5	27.18	3.88	0.093	17.62	3.88	0.550	15.00	9.71	0.407	15.81	8.25	0.012	14.35	8.05	0.032
		Exam II	5	20.44	9.60	***	15.41	8.87	***	15.27	9.28	***	14.39	7.90	***	13.51	8.17	***
	Right	Exam I	6	26.42	7.06	0.737	17.06	6.90	0.572	17.32	8.36	0.683	15.66	9.10	0.133	14.46	10.85	0.606
		Exam II	6	24.50	9.08	***	20.28	8.94	***	19.08	7.16	***	14.19	8.97	***	14.23	10.29	***
Follow-up																		
25-44 years	Left	Exam II	5	-	-	-	15.41	8.87	0.669	15.27	9.28	0.675	14.39	7.90	0.728	13.51	8.17	0.785
		Exam III	5	-	-	-	18.12	8.36	***	17.96	8.22	***	12.32	8.57	***	11.54	9.99	***
	Right	Exam II	6	24.50	9.08	0.843	20.28	8.94	0.663	19.08	7.16	0.772	14.19	8.97	0.847	14.23	10.29	0.950
		Exam III	6	24.43	9.44	***	18.46	7.70	***	17.99	7.14	***	15.23	6.27	***	14.59	6.04	***
After rehabilitation																		
45-60 years	Left	Exam I	16	25.86	8.06	0.988	14.88	7.79	0.495	14.70*	9.25-23.08*	0.064	12.38*	8.44-16.13*	0.173	13.28*	9.59-16.18*	0.859
		Exam II	16	25.81	8.35	***	16.93	8.00	***	15.29*	11.46-20.82*	**	14.25*	9.07-17.35*	**	13.34*	9.60-17.33*	**
	Right	Exam I	12	24.55	4.75	0.938	17.90	6.37	0.334	13.91*	11.96-17.50*	1.000	12.79	3.39	0.905	13.37	3.81	0.070
		Exam II	12	24.41	4.30	***	15.49	4.38	***	13.67*	12.37-18.16*	**	12.86	4.05	***	12.75	3.96	***
Follow-up																		
45-60 years	Left	Exam II	16	25.81	8.35	0.263	16.93	8.00	0.447	16.97	8.08	0.464	14.61	6.84	0.130	14.48	6.44	0.590
		Exam III	16	26.27	8.11	***	15.62	6.56	***	15.62	6.68	***	11.54	5.20	***	13.52	5.63	***
	Right	Exam II	12	24.41	4.30	0.976	15.49	4.38	0.787	14.88	3.91	0.786	12.86	4.05	0.724	12.75	3.96	0.769
		Exam III	12	24.42	4.47	***	15.97	6.10	***	15.38	6.03	***	13.50	5.57	***	13.36	6.35	***

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

Statistical Analysis

The results are presented using descriptive statistics (mean, standard deviation, quartile). When analyzing the differences between the dependent variables, the *t* test for dependent samples was used, after prior verification of the normality of the distributions of the variables with the Kolmogorov-Smirnov

test. Correlations between the variables were assessed by the Pearson correlation coefficient. A significance level of *P*<0.05 was used. The calculation was performed with the STATISTICA package version 10.0 (StatSoft).

Table 3. The effect of rehabilitation on the amount of fat in age group 61 to 75 and >75 years.

Age	Side of paresis	Exam	N	FAT			FAT right lower limb			FAT left lower limb			FAT right arm			FAT left arm		
				Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P
After rehabilitation																		
61-75 years	Left	Exam I	12	27.85	7.22	0.443	21.61	6.95	0.129	14.79*	12.57-22.95*	0.314	13.20	5.05	0.867	14.94	5.66	0.221
		Exam II	12	25.81	3.98	***	17.21	5.38	***	15.75*	12.72-22.95*	**	13.14	4.96	***	14.58	5.40	***
	Right	Exam I	18	24.03	7.59	0.517	16.67	7.70	0.663	17.63*	11.57-22.75*	0.756	13.98*	11.43-15.24*	0.509	12.68*	10.91-16.28*	0.937
		Exam II	18	25.72	6.82	***	17.86	7.73	***	16.58*	11.57-22.09*	**	13.52*	11.01-18.75*	**	12.31*	10.19-18.00*	**
Follow-up																		
61-75 years	Left	Exam II	12	25.81	3.98	0.988	17.21	5.38	0.051	17.46	5.38	0.066	13.14	4.96	0.218	14.58	5.40	0.420
		Exam III	12	25.80	5.23	***	21.39	8.21	***	21.12	7.62	***	16.83	7.13	***	16.73	7.35	***
	Right	Exam II	18	25.72	6.82	0.197	17.86	7.73	0.619	17.67	7.63	0.626	15.82	7.33	0.934	15.31	7.70	0.678
		Exam III	18	26.08	6.85	***	19.38	8.25	***	19.21	8.45	***	16.05	7.87	***	16.53	8.52	***
After rehabilitation																		
>75 years	Left	Exam I	6	27.20	8.80	0.780	17.99	9.22	0.509	22.08	7.82	0.917	17.90	7.37	0.689	19.50	8.93	0.316
		Exam II	6	28.85	7.01	***	21.62	8.02	***	22.13	6.97	***	17.67	6.93	***	18.90	8.31	***
	Right	Exam I	5	32.26	5.34	0.587	23.58	7.98	0.801	21.75	9.96	0.662	18.74	8.76	0.258	19.57	9.23	0.071
		Exam II	5	28.99	9.98	***	22.07	9.09	***	21.64	9.88	***	18.26	8.38	***	18.91	9.21	***
Follow-up																		
>75 years	Left	Exam II	6	28.85	7.01	0.667	21.62	8.02	0.580	22.13	6.97	0.661	17.67	6.93	0.599	18.90	8.31	0.700
		Exam III	6	28.49	7.53	***	22.93	6.96	***	23.15	7.79	***	19.17	6.03	***	20.38	7.27	***
	Right	Exam II	5	28.99	9.98	0.819	22.07	9.09	0.924	21.64	9.88	0.935	18.26	8.38	0.904	18.91	9.21	0.763
		Exam III	5	29.07	10.59	***	21.61	8.78	***	21.23	8.32	***	17.85	5.78	***	17.34	7.04	***

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

Results

The change in fat content of the patients was analyzed as a whole and divided into lower right, lower left, upper right, and upper left limbs, taking into account the age of the patients and the side of the paresis. It was noted that people with left-sided paresis who were in the youngest age group

(25-44 years) had a reduction in the fat content of the healthy ($P=0.012$) and paresis upper limbs ($P=0.032$; **Table 2**). In older age groups, there was no statistically significant change in fat content between examinations I and II and examinations II and III (**Table 3**). In view of the patients' fat content, it was noted that in left-sided paresis in the youngest age group (25-44 years), the muscle tissue content in the upper right

Table 4. The effect of rehabilitation on the amount of muscle mass in age groups 25 to 44 and 45 to 60 years.

Age	Side of paresis	Exam	N	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P
				median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*	
PMM																		
PMM right lower limb																		
PMM left lower limb																		
PMM right arm																		
PMM left arm																		
After rehabilitation																		
25-44 years	Left	Exam I	5	69.20	3.74	0.096	40.02	2.00	0.527	41.38	4.72	0.552	40.95	3.88	0.010	41.75	3.78	0.265
		Exam II	5	75.58	9.19	***	41.18	4.35	***	41.28	4.53	***	41.68	3.69	***	41.97	3.67	***
	Right	Exam I	6	69.88	6.66	0.732	40.32	3.44	0.577	39.21	3.66	0.674	41.10	4.33	0.207	41.50	5.29	0.560
		Exam II	6	71.73	8.64	***	38.74	4.44	***	39.30	3.56	***	41.75	4.51	***	41.63	5.03	***
Follow-up																		
25-44 years	Left	Exam II	5	75.58	9.19	0.701	41.18	4.35	0.672	41.28	4.53	0.666	41.68	3.69	0.737	41.97	3.67	0.779
		Exam III	5	72.73	12.85	***	39.86	4.14	***	39.92	4.06	***	42.65	4.34	***	42.93	4.96	***
	Right	Exam II	6	71.73	8.64	0.443	38.74	4.44	0.651	39.30	3.56	0.741	41.75	4.51	0.883	41.63	5.03	0.990
		Exam III	6	78.81	24.78	***	39.65	3.76	***	39.90	3.49	***	41.36	3.03	***	41.67	2.94	***
After rehabilitation																		
45-60 years	Left	Exam I	16	70.44	7.67	0.973	41.44	3.83	0.482	41.62*	37.37-44.17*	0.077	42.58*	40.70-44.34*	0.278	42.26*	40.73-44.04*	0.929
		Exam II	16	70.54	7.86	***	40.39	3.91	***	41.31*	38.45-43.13*	**	41.75*	40.08-44.64*	**	42.31*	40.14-43.96*	**
	Right	Exam I	12	71.64	4.54	0.925	39.91	3.10	0.327	41.90*	40.08-42.95*	0.859	42.28	1.69	0.823	41.94	1.93	0.051
		Exam II	12	71.79	4.07	***	41.11	2.20	***	41.92*	39.75-42.68*	**	42.22	1.99	***	42.30	1.98	***
Follow-up																		
45-60 years	Left	Exam II	16	71.06*	66.47-76.67*	0.049	40.39	3.91	0.473	40.41	3.98	0.500	41.58	3.34	0.136	41.60	3.20	0.605
		Exam III	16	63.29*	52.42-73.64*	*	41.00	3.25	***	41.03	3.33	***	43.04	2.51	***	42.06	2.71	***
	Right	Exam II	12	71.79	4.07	0.377	41.11	2.20	0.813	41.41	1.99	0.799	42.22	1.99	0.724	42.30	1.98	0.791
		Exam III	12	76.11	17.91	***	40.90	3.00	***	41.17	3.04	***	41.91	2.69	***	42.02	3.09	***

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

(healthy) limb ($P=0.010$) was increased after rehabilitation. In addition, the control study found a decrease in the overall muscle tissue content, including in people with left-sided paresis ($P=0.049$; **Table 4**).

Results of the follow-up examination showed that in people with left-sided paresis at the age of 61 to 75 years, the muscle

content of the healthy lower limb was significantly reduced ($P=0.048$; **Table 5**).

The changes in body mass of the persons after stroke were then analyzed and considered the time elapsed since the stroke incident and the side of paresis. We found that in the period from 2 to 3 months after stroke and with left-sided paresis,

Table 5. The effect of rehabilitation on the amount of muscle mass in age groups 61 to 75 and >75 years.

Age	Side of paresis	Exam	N	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P
				median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*	
PMM																		
PMM right lower limb																		
PMM left lower limb																		
PMM right arm																		
PMM left arm																		
After rehabilitation																		
61-75 years	Left	Exam I	12	68.54	6.87	0.449	38.09	3.41	0.136	41.45*	37.47-42.54*	0.260	41.14	3.24	0.495	41.45	2.66	0.224
		Exam II	12	70.44	3.79	***	40.26	2.71	***	40.95*	37.47-42.41*	**	40.89	3.48	***	41.64	2.51	***
	Right	Exam I	18	72.16	7.21	0.516	40.54	3.80	0.651	40.08*	37.57-43.06*	0.820	42.01*	40.95-42.86*	0.551	42.33*	40.70-43.37*	0.937
		Exam II	18	70.55	6.47	***	39.94	3.80	***	40.64*	37.79-43.06*	**	42.01*	39.58-43.12*	**	42.57*	40.00-43.64*	**
Follow-up																		
61-75 years	Left	Exam II	12	70.44	3.79	0.588	40.26	2.71	0.048	40.13	2.69	0.063	42.29	2.32	0.212	41.64	2.51	0.407
		Exam III	12	68.39	12.85	***	38.19	3.99	***	38.32	3.71	***	40.52	3.32	***	40.58	3.51	***
	Right	Exam II	18	70.55	6.47	0.448	39.94	3.80	0.637	40.03	3.78	0.648	40.89	3.48	0.990	41.16	3.72	0.664
		Exam III	18	73.62	16.76	***	39.23	4.08	***	39.32	4.18	***	40.87	3.65	***	40.54	4.11	***
After rehabilitation																		
>75 years	Left	Exam I	6	69.12	8.40	0.781	39.97	4.53	0.492	37.89	3.81	0.926	40.03	3.45	0.670	39.25	4.27	0.303
		Exam II	6	67.56	6.67	***	38.10	3.94	***	37.87	3.38	***	40.15	3.24	***	39.56	3.95	***
	Right	Exam I	5	64.30	5.07	0.584	37.18	3.92	0.791	38.06	4.89	0.445	38.52	4.11	0.243	39.14	4.34	0.071
		Exam II	5	67.44	9.51	***	37.95	4.52	***	38.16	4.92	***	39.76	3.91	***	39.47	4.35	***
Follow-up																		
>75 years	Left	Exam II	6	67.56	6.67	0.796	38.10	3.94	0.574	37.87	3.38	0.636	40.15	3.24	0.591	39.56	3.95	0.711
		Exam III	6	65.43	18.64	***	37.47	3.42	***	37.34	3.85	***	39.41	2.80	***	38.85	3.52	***
	Right	Exam II	5	67.44	9.51	0.741	37.95	4.52	0.953	38.16	4.92	0.951	39.76	3.91	0.880	39.47	4.35	0.770
		Exam III	5	64.58	19.11	***	38.09	4.34	***	38.31	4.15	***	40.01	2.68	***	40.21	3.34	***

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

there was a reduction in the content of adipose tissue in the paresis upper limb ($P=0.047$; **Table 6**)

Many more changes were seen among patients between 7 and 12 months after stroke. In patients with right-sided paresis, the fat content of the lower paresis limb ($P=0.027$), the upper paresis limb ($P=0.023$), and the healthy upper limb ($P=0.033$)

decreased after rehabilitation. Among patients with left-sided paresis, an increase in the fat content of the lower paresis limb was observed ($P=0.028$). A similar result was observed in the lower healthy limb in patients who were at least 12 months after stroke ($P=0.042$). In the follow-up examination in people more than 12 months after stroke with left-sided paresis, the level of fat in the healthy lower limb increased (**Table 7**).

Table 6. The effect of rehabilitation on the amount of fat at 2 to 3 and 4 to 6 months after stroke.

Time after stroke	Side of paresis	Exam	N	FAT			FAT right lower limb			FAT left lower limb			FAT right arm			FAT left arm		
				Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P
After rehabilitation																		
2-3 months	Left	Exam I	6	27.59	3.61	0.072	17.01	3.78	0.632	13.99	9.03	0.262	11.03*	10.26-19.64*	0.345	14.27	7.20	0.047
		Exam II	6	21.62	9.06	***	15.55	7.94	***	15.12	8.30	***	12.78*	9.68-17.54*	**	13.59	7.31	***
	Right	Exam I	6	29.01	3.66	0.242	18.69	3.63	0.856	18.77	7.12	0.908	14.56	8.41	0.761	12.45	10.05	0.700
		Exam II	6	23.49	8.75	***	19.37	8.05	***	18.82	6.99	***	14.36	9.06	***	12.55	9.77	***
Follow-up																		
2-3 months	Left	Exam II	6	21.63*	13.25-27.56*	0.180	15.55	7.94	0.746	15.12	8.30	0.687	14.58	7.08	0.537	13.59	7.31	0.676
		Exam III	6	21.93*	13.25-28.40*	**	17.22	7.79	***	17.22	7.58	***	11.51	7.92	***	11.13	8.99	***
	Right	Exam II	6	23.49	8.75	0.790	19.37	8.05	0.578	18.82	6.99	0.634	14.36	9.06	0.881	12.55	9.77	0.591
		Exam III	6	23.40	9.12	***	16.95	6.98	***	16.98	6.84	***	15.16	6.26	***	15.55	5.79	***
After rehabilitation																		
4-6 months	Left	Exam I	7	23.78	5.63	0.323	11.47	3.10	0.068	17.59	12.92-26.67	0.893	15.22*	10.84-16.67*	0.225	15.86	7.36	0.915
		Exam II	7	26.46	7.66	***	18.12	7.74	***	17.08	12.92-22.09	**	15.65*	12.82-22.97*	**	15.80	6.56	***
	Right	Exam I	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Exam II	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Follow-up																		
4-6 months	Left	Exam II	7	24.88*	23.40-34.97*	0.465	18.12	7.74	0.459	18.18	7.32	0.365	17.01	6.27	0.215	15.80	6.56	0.765
		Exam III	7	27.29*	23.25-34.97*	**	15.63	7.12	***	15.02	7.34	***	12.36	5.99	***	14.85	6.78	***
	Right	Exam II	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Exam III	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

The analysis of the change in muscle tissue content due to rehabilitation did not show any statistically significant changes in patients between 2 and 3 months after stroke, as well as in patients between 4 and 6 months after the onset of the stroke incident (Table 8).

In contrast, in patients between 7 and 12 months after stroke with right-sided paresis, an increase in muscle tissue content in the lower paresis limb ($P=0.030$), upper paresis limb ($P=0.037$), and healthy upper limb ($P=0.034$) was observed, which indicated a positive result of the rehabilitation. In people with left-sided paresis more than 12 months after stroke, muscle tissue was reduced in the healthy limbs (Table 9).

Table 7. The effect of rehabilitation on the amount of fat at 7 to 12 and >12 months after stroke.

Time after stroke	Side of paresis	Exam	N	FAT			FAT right lower limb			FAT left lower limb			FAT right arm			FAT left arm		
				Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P	Mean median*	SD Q1-Q3*	P
After rehabilitation																		
7-12 months	Left	Exam I	8	27.21	10.18	0.716	17.97	9.96	0.704	13.18*	7.35-22.08*	0.028	12.16	7.20	0.387	13.36	7.15	0.877
		Exam II	8	25.03	9.87	***	15.97	9.12	***	14.27*	9.31-22.73*	**	12.39	7.41	***	13.39	7.00	***
	Right	Exam I	7	22.75	4.86	0.625	19.34	4.57	0.027	14.04	3.85	0.456	11.19	2.87	0.023	11.60	2.51	0.033
		Exam II	7	21.78	1.84	***	13.86	3.85	***	13.81	3.73	***	10.08	2.09	***	10.59	1.84	***
Follow-up																		
7-12 months	Left	Exam II	8	25.03	9.87	0.563	15.97	9.12	0.999	16.24	9.54	0.945	12.39	7.41	0.678	13.39	7.00	0.848
		Exam III	8	25.48	9.42	***	15.98	6.90	***	16.40	6.91	***	11.34	4.90	***	12.91	4.86	***
	Right	Exam II	7	21.78	1.84	0.826	13.86	3.85	0.312	13.81	3.73	0.472	10.08	2.09	0.197	10.59	1.84	0.295
		Exam III	7	21.66	2.49	***	16.31	5.84	***	15.76	5.55	***	13.55	6.12	***	13.72	7.09	***
After rehabilitation																		
>12 months	Left	Exam I	18	27.63	7.53	0.747	20.40	7.70	0.509	18.91*	12.59-24.38*	0.307	14.76	6.14	0.680	16.46	7.00	0.096
		Exam II	18	26.83	5.19	***	18.68	6.49	***	18.72*	13.09-24.52*	**	14.65	5.90	***	16.02	6.60	***
	Right	Exam I	27	25.26	7.59	0.429	16.99	8.29	0.411	18.64*	12.69-25.95*	0.493	14.04*	11.43-22.06*	0.289	15.00*	10.91-22.95*	0.446
		Exam II	27	26.92	7.08	***	18.88	7.80	***	17.48*	12.44-23.65*	**	14.29*	11.01-20.90*	**	16.04*	10.19-22.06*	**
Follow-up																		
>12 months	Left	Exam II	18	26.83	5.19	0.779	18.68	6.49	0.042	19.02	6.18	0.063	14.65	5.90	0.167	16.02	6.60	0.357
		Exam III	18	26.70	6.01	***	21.90	7.64	***	21.80	7.51	***	17.61	6.70	***	17.94	7.32	***
	Right	Exam II	27	26.92	7.08	0.190	18.88	7.80	0.712	18.35	7.66	0.667	16.42	6.90	0.860	16.48	7.50	0.849
		Exam III	27	27.19	7.16	***	19.69	8.16	***	19.32	8.20	***	16.07	7.16	***	16.06	7.88	***

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

Discussion

The aim of the study was to evaluate the effects of rehabilitation in terms of changes in the body mass composition in the upper and lower limbs depending on the length of time after stroke and the age of the patients. Currently, studies suggest that in patients after stroke, there is a change in body mass

composition, such as adipose tissue, muscle tissue, fat-free tissue, and bone tissue, and in the amount of water content in the body [10,13,36,37].

After a stroke, especially in the acute period, sarcopenia can be noticed, with loss of muscle mass and strength. Stroke rehabilitation should therefore be introduced as soon as possible

Table 8. The effect of rehabilitation on the amount of muscle mass at 2 to 3 and 4 to 6 months after stroke.

Time after stroke	Side of paresis	Exam	N	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	
				median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		
PMM																			
After rehabilitation																			
2-3 months	Left	Exam I	6	68.81	3.48	0.074	40.32	1.93	0.603	41.87	4.39	0.289	42.95*	39.29-43.59*	0.345	41.73	3.38	0.145	
		Exam II	6	74.47	8.66	***	41.11	3.89	***	41.34	4.06	***	42.33*	40.35-43.75*	**	41.96	3.28	***	
	Right	Exam I	6	67.44	3.44	0.240	39.50	1.78	0.862	39.46	3.52	0.920	41.62	4.02	0.967	42.49	4.99	0.779	
		Exam II	6	72.68	8.32	***	39.18	4.01	***	39.44	3.46	***	41.63	4.56	***	42.46	4.85	***	
	Follow-up																		
	2-3 months	Left	Exam II	6	74.47	8.66	0.459	41.11	3.89	0.755	41.34	4.06	0.681	41.59	3.31	0.555	41.96	3.28	0.683
Exam III			6	69.69	13.70	***	40.31	3.86	***	40.30	3.74	***	43.00	3.98	***	43.10	4.46	***	
Right		Exam II	6	72.68	8.32	0.255	39.18	4.01	0.560	39.44	3.46	0.596	41.63	4.56	0.909	42.46	4.85	0.631	
		Exam III	6	83.48	23.99	***	40.40	3.37	***	40.44	3.34	***	41.32	3.04	***	41.11	2.81	***	
After rehabilitation																			
4-6 months	Left	Exam I	7	72.47	5.31	0.309	43.10	1.53	0.064	40.12*	35.76-42.44*	0.893	41.30*	40.35-43.37*	0.225	41.02	3.53	0.511	
		Exam II	7	69.94	7.15	***	39.79	3.79	***	40.37*	37.79-42.44*	**	40.87*	37.84-42.31*	**	40.88	3.36	***	
	Right	Exam I	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Exam II	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Follow-up																		
	4-6 months	Left	Exam II	7	71.38*	61.84-72.67*	0.735	39.79	3.79	0.451	39.81	3.59	0.371	40.37	3.03	0.222	40.88	3.36	0.743
Exam III			7	65.84*	62.53-80.98*	**	41.03	3.51	***	41.35	3.68	***	42.58	2.95	***	41.42	3.33	***	
Right		Exam II	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Exam III	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

to prevent worsening of muscle mass loss and strength function [37-39].

In the present study, the most positive changes were seen among people between 7 and 12 months after stroke with right-sided paresis. These changes included a reduction in fat content and an increase in muscle tissue in the lower and upper

paresis limbs, as well as in the healthy upper limb after rehabilitation. We suppose that this may have been due to the fact that patients after stroke have already adopted a new life situation, have returned to the natural home environment, and have the greatest motivation for rehabilitation to regain their "old" life. It is worth emphasising that patients in the early post-stroke period often struggle with depression and reluctance to

Table 9. The effect of rehabilitation on the amount of muscle mass at 7 to 12 and >12 months after stroke.

Time after stroke	Side of paresis	Exam	N	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P	Mean	SD	P
				median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*		median*	Q1-Q3*	
PMM																		
After rehabilitation																		
7-12 months	Left	Exam I		69.11	9.69	0.705	39.93	4.90	0.713	42.38*	37.88-45.03*	0.043	42.68	3.46	0.993	42.18	3.43	0.986
		Exam II		71.27	9.34	***	40.88	4.46	***	41.80*	37.54-44.17*	**	42.69	3.62	***	42.19	3.37	***
	Right	Exam I		73.34	4.64	0.620	39.24	2.26	0.030	41.89	1.95	0.625	43.06	1.46	0.037	42.76	1.31	0.034
		Exam II		74.29	1.74	***	41.94	1.95	***	41.96	1.94	***	43.53	1.20	***	43.30	0.93	***
Follow-up																		
7-12 months	Left	Exam II		71.27	9.34	0.039	40.88	4.46	0.922	40.78	4.71	0.882	42.69	3.62	0.669	42.19	3.37	0.869
		Exam III		60.53	15.57	***	40.78	3.41	***	40.60	3.42	***	43.22	2.33	***	42.39	2.27	***
	Right	Exam II		74.29	1.74	0.375	41.94	1.95	0.314	41.96	1.94	0.459	43.53	1.20	0.217	43.30	0.93	0.315
		Exam III		81.26	19.40	***	40.71	2.87	***	40.94	2.78	***	41.88	3.03	***	41.82	3.53	***
After rehabilitation																		
>12 months	Left	Exam I		68.73	7.17	0.753	38.72	3.79	0.528	39.40*	36.88-42.47*	0.280	41.50	2.88	0.614	40.71	3.33	0.093
		Exam II		69.48	4.93	***	39.54	3.22	***	39.42*	36.81-42.18*	**	41.58	2.76	***	40.95	3.11	***
	Right	Exam I		70.99	7.22	0.432	40.38	4.08	0.410	39.55*	35.88-42.64*	0.738	41.86*	38.24-42.86*	0.274	41.67*	37.68-43.37*	0.528
		Exam II		69.41	6.72	***	39.44	3.83	***	40.21*	36.95-42.58*	**	41.67*	38.67-43.12*	**	40.82*	38.24-43.64*	**
Follow-up																		
>12 months	Left	Exam II		69.48	4.93	0.553	39.54	3.22	0.039	39.38	3.04	0.057	41.58	2.76	0.161	40.95	3.11	0.353
		Exam III		67.40	14.53	***	37.95	3.72	***	37.99	3.67	***	40.15	3.12	***	40.00	3.51	***
	Right	Exam II		69.41	6.72	0.674	39.44	3.83	0.724	39.71	3.79	0.688	40.61	3.27	0.779	40.59	3.60	0.836
		Exam III		70.69	16.18	***	39.07	4.04	***	39.26	4.07	***	40.86	3.32	***	40.81	3.79	***

* Median (Q1-Q3); ** Wilcoxon test; *** T-test.

rehabilitate and experience defeats and failures in the use of paresis limbs, especially if the paresis is in the dominant limb [40-42]. Numerous studies indicate the presence and influence of neglect on rehabilitation in persons after stroke [43-47]. Neglect is a common neuropsychological disorder after right hemisphere stroke, such as in people with left-sided paresis, and research indicates that neglect worsens the prognosis of

functional recovery and causes poor rehabilitation outcomes [43-47]. In our present study, patients with right-sided paresis achieved the best results, which confirms the above theory, because all of our patients were right-handed; therefore, it can be assumed that when the early period of time has passed due to reduced motivation to exercise as a result of illness, their movement activity was intensified in the dominant right limb.

In turn, when analyzing the effects of age on the rehabilitation effects of body mass change, in our present study it was shown that only in the youngest age group (25-44 years) and with left-sided paresis, the fat content of the upper limb was reduced in the healthy and paresis limbs, and the muscle content of the upper right (healthy) limb was increased after rehabilitation. We suppose that this may be due to the fact that younger patients are, by definition, in better condition and more physically fit. Owing to the lower risk of age-related multi-disease burden and involuntional changes in particular systems of the human body in younger patients, they can achieve better rehabilitation results in terms of changes in body mass composition than the elderly after stroke. The elderly have senile processes in terms of all systems, including the musculoskeletal system, which is characterized by inter alia, muscle relaxation, weakening of muscle strength, and muscle atrophy and results from the poor condition of blood vessels causing poorer nutrition of the muscles. Studies have shown a decrease in body mass in elderly patients after stroke and a loss of muscle and fat mass [48-51]. This hypothesis was confirmed by the fact that our control study showed that in people with left-sided paresis at the age of 61 to 75 years, the muscle tissue content of the healthy lower limb significantly decreased, which may have been because elderly people who are older after a stroke often limit physical activity and mobility, which is due to limited activity and inactivity in all systems, including muscle tissue reduction [48-51]. Since the effects described above only applied to patients with left-sided paresis, and therefore to those whose dominant arm was the healthy one, was likely because these patients already at the beginning had easier situations than patients with right-sided paresis, because they could become more involved in the exercise and work with the therapist, making the most of the dominant healthy upper limb in helping the other, the paresis limb, to work and exercise.

In the available literature, there are few studies on the components of body mass in the upper limbs with paralysis among people after stroke that consider age and time from the onset of stroke. Knowing the content of muscle tissue and adipose tissue in the upper and lower limbs before the planned rehabilitation would allow for the targeting and selection of appropriate techniques, methods, and exercises for a patient's condition.

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It is also necessary to continue the research, while considering the segmental assessment of body mass composition.

Limitations

Despite our efforts, this study had certain limitations. First, the analysis was carried out only among patients who had ischemic stroke and only in right-handed patients. In subsequent studies, the group will be expanded to include patients with hemorrhagic stroke and left-handedness. The second limitation may be the segmental assessment of only the adipose and muscle tissue in the limbs of patients after a stroke with regard to age and time since stroke. However, the study did not consider the body mass composition of the whole body, owing to the isolation and evaluation of the effects of rehabilitation in terms of changes in the body mass composition in the upper and lower limbs. An interesting analysis could also be the assessment of the correlation between the body mass composition and the level of physical activity in patients after stroke. It would be worth considering the inclusion of such analysis in future studies.

Conclusions

The rehabilitation program has had a significant impact on the change in the composition of body mass in upper limbs and lower limbs in people with right-sided paresis, in particular 7 to 12 months after stroke. We suspect that this may have been because the patients were right-handed and therefore their exercise was intensified in the upper and lower right limbs. The results obtained may be useful in planning a rehabilitation program for stroke patients that considers the patient's dominant side and neglect.

Under the influence of hospital rehabilitation in the youngest age group (25-44 years) muscle tissue growth was observed, and adipose tissue was reduced in the upper limbs in patients with left-sided paresis. This may indicate the need for specific activation of older people who are more likely to have co-existing diseases and lower functional efficiency than those of a younger age.

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