Baltic Journal of Health and Physical Activity

Volume 15 | Issue 3 Article 5

2023

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Recommended Citation

Olczak A, Dornowski M. The level of functionality of the affected upper limb in stroke patients depends on the type of therapy used and the lateralization of the subjects' body – A randomized observational study. Balt J Health Phys Act. 2023;15(3):Article5. https://doi.org/10.29359/BJHPA.15.3.05

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Keywords

stroke, dominant upper limb, non–dominant upper limb, motor coordination, trunk stabilization exercises, NDT Bobath concept

Baltic Journal
of Health and Physical Activity
e-ISSN 2080-9999

Article

The level of functionality of the affected upper limb in stroke patients depends on the type of therapy used and the lateralization of the subjects' body – A randomized observational study

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Academic Editor: Agnieszka Maciejewska-Skrendo

Received: February 2023
Accepted: July 2023
Published: September 2023

1. Introduction

The mobility of the human body depends on various functions of the upper and lower limbs as well as the left and right limbs, i.e. functional asymmetry [1, 2]. The different functions and movements of the hands contribute to their coordination and specialization. When the dominant hand (right-handed, left-handed) performs the main activity, the secondary hand supports it. Coordination of the dominant and subordinate hand allows for a high degree of dexterity, thanks to which a high level of perception and economy of movements can be achieved when one of the limbs dominates and the other supports it and cooperates with it [3]. If the dominant hand is on the same side of the body as the dominant eye, the hand-eye system is formed, which is the basis of eye-hand coordination. This enables and significantly facilitates the performance of manipulative and graphic activities [4, 5, 6].

The dominance of the side of the human body develops gradually in the progressive process of lateralization. With age and general motor development, it strengthens and remains constant throughout adult life [7]. Lateralization, one-sidedness, or functional asymmetry of the right and left sides of the human body results from the differences in the structure and functions of both cerebral hemispheres and is a consequence of the domination of one of the hemispheres [8]. It is expressed, inter alia, in greater mobility of the right than the left limbs, as well as the registration by the brain of a greater number of sensory stimuli coming from one side of the body [1, 9].

Stabilization of the human body is an important aspect that enables the performance of selective, coordinated movements, as well as forms the basis for maintaining balance [10, 11, 12]. Many researchers believe that a stable trunk is the most important element of the body posture control mechanism [13, 14, 15]. On the other hand, the ability to synchronize rhythmically moving limbs and limb segments is one of the most basic skills of vertebrates and invertebrates [16]. Trunk control is recognized as important to the functional abilities of the upper limb. Wee et al. [17] investigated the importance of trunk support in the lumbar region in a sitting position for the functional abilities of the upper limb and confirmed this hypothesis.

This work focuses on the use of various therapies in post-stroke patients to determine which one is more effective in restoring the function of the affected upper limb. A therapy based on the NDT Bobath concept has been chosen and compared with the classic rehabilitation of a stroke patient. Moreover, since patients have right or left-sided functional disorders, we wanted to look at whether there is a difference in the results obtained from the right or the left upper limb depending on the treatment used and whether or not the limb is dominant.

In studies comparing the NDT Bobath concept with other exercises, the described concept plays a greater role in the possibility of trunk stabilization [18]. Desouzart [19] wrote about the effectiveness of the NDT Bobath concept in improving motor parameters in children with cerebral palsy, especially in terms of general mobility, postural control, and stability. Keser et al. [20] also emphasized the importance of NDT Bobath in working with patients with multiple sclerosis [20]. However, when comparing the NDT Bobath concept and the PNF method in working with stroke patients in order to improve the motor control of the torso, both work options turned out to be effective [21]. However, after analyzing the literature, no studies were found in which the authors would show the effect of torso stabilization exercises according to the NDT Bobath concept on the functional improvement of the upper limbs, and that researchers would analyze whether a given therapy was more effective for the affected dominant or non-dominant upper limb.

Therefore, the aim of our study was to analyze the possibility of influencing, through therapy, changes in the activity of the affected upper limb in patients after ischemic stroke. Is has been assumed that the applied trunk stabilization exercises would improve the functional assessment of the affected upper limb. At the same time, the study investigates whether lateralization of the body had an impact on the results after the application of the therapy.

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2. Materials and Methods

2.1. Trial design

The trial was a randomized double-blinded study of 10 days' duration. The patients were divided into two groups: the study and the control one, which were subjected to different therapies (independent variables). The study group consisted of 30 people. Their physiotherapy was based on exercises that heavily employed the core muscles to equalize tension and strength, according to the NDT Bobath concept. The control group also consisted of 30 patients. In this group, classical therapy was used in patients after a stroke.

All patients were examined the first time after their admission to the rehabilitation clinic and the second time after 10 days of therapy. Assessment games were used for the study, which are the software of the Armeo®Spring device and proprietary tests, "wall" and "abacus" (dependent variables).

Criteria for inclusion in the stroke group were as follows: 1) patients with ischemic stroke, 2) patients with hemiparesis after 5 to 6 weeks after stroke, 3) subjects with poor trunk control (the Trunk Control Test at 48–61 points), 4) subjects who were in a functional state allowing movements of the upper extremity (FMA-UE at 43–49 motor function points), 5) muscle tension (MAS 0-1+), 6) no severe deficits in communication, memory, or understanding which could impede proper measurement performance, 7) at least 35 years of age; maximum 85 years of age.

Criteria for exclusion from the stroke group were as follows: 1) lack of possibility to adjust the orthosis to the patient's treated limb, 2) bone instability (ununited fractures, advanced osteoporosis), 3) permanent contracture of the treated limb, 4) open skin lesions in the area of the treated upper limb, 5) sensory disturbances, 6) shoulder subluxation or pain, 7) increased spasticity, 8) increased involuntary movements, e.g. ataxia, dyskinesia, myoclonic seizures, 9) unstable life functions: contraindications related to the respiratory system or the cardiovascular system (instability or the need to use supportive devices), 10) the need for long-term intravenous therapy, 11) postural instability, 12) contraindication to a sitting position, 13) confused or uncooperative patients, 14) severe cognitive impairment, 15) patients requiring isolation due to infections, 16) severe vision problems (the patient is unable to observe the elements displayed on the computer screen), 17) epilepsy.

2.2. Patients

In total 80 stroke patients were examined. Following the exclusion criteria, 20 people were excluded because of the period of the disease (5 people), their functional condition (10 people), and some refused to participate (5 people). The National Institute for Health Stroke Scale (NIHSS) [22] was used to identify the neurological deficit and to evaluate the patients' overall physical impairment. To assess the functional state of the upper limb, the FMA UE test was used; to assess the stability of the trunk – Trunk Control Test (TCT), and to assess the tension of the muscle – the Ashworth modified scale (MAS) [23, 24, 25]. The flow of participants through each stage of the study is shown below (Fig. 1).

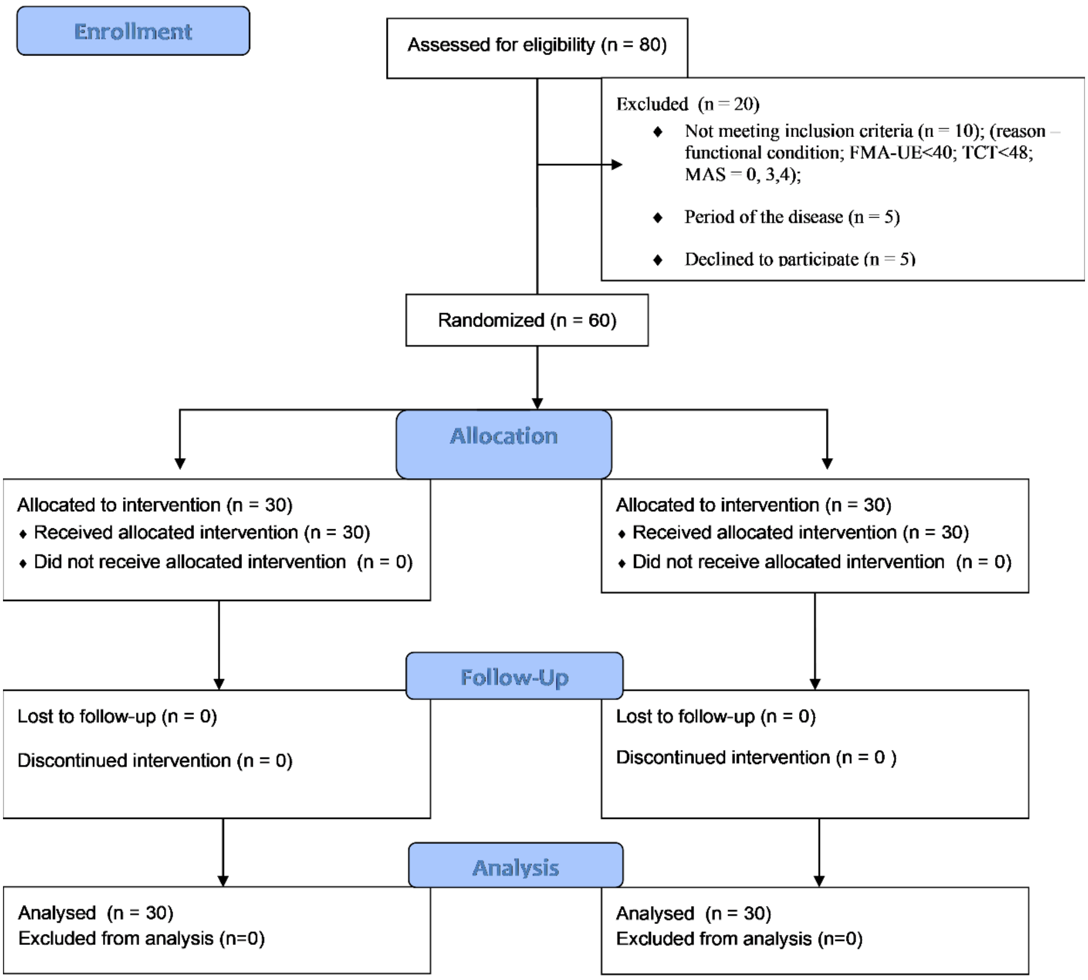

Figure 1. The flow of participants through each stage of the study

Sixty patients after ischemic cerebral stroke (men and women, mean age 65.83±10.40 years) were randomly recruited from among patients of the Rehabilitation Clinic of the Military Institute of Medicine – National Research Institute in Warsaw, Poland.

Patients were in the acute phase of the disease (5–7 weeks post-stroke), with slight neurological deficits (NIHSS ≤7), trunk stabilization from 48 to 61 points in TCT, the functional state of the upper limb – enabling movements (FMA EU from 43–49 motor function points, and normal sensation/light touch. The muscles tone was measured with the Modified Ashworth Scale (MAS 1/1 +). The clinical evaluation of patients after a stroke was performed by the physician admitting the patient to the clinic on the day of admission. The characteristics of the patients were shown in Table 1 and Table 2.

Finally, 60 patients were randomly divided into the study group (30 people) and the control group (30 people). In the study group, exercises to stabilize the trunk were used in accordance with the NDT Bobath concept, while in the control group, classic exercises were used.

Table 1. Demographic characteristics of stoke participants

Characteristics	Mean ± Standard Deviation	
Group	Study	Control
Age (years)	65.27 ± 10.56	66.40 ± 10.40
Height (cm)	166.77 ± 8.39	168.67 ± 7.81
Weight (kg)	79.77 ± 13.09	78.80 ± 12.82

Table 2. The basic epidemiological data of the study and control stroke participants

Participants	n = 60 (100%)	
Post-stroke groups	Study	Control
n/%	30 (50%)	30 (50%)
Female	15 (50%)	15 (50%)
Male	15 (50%)	15 (50%)
Cerebral ischemic stroke (thromboembolic) n/%	30 (100%)	30 (100%)
Time post stroke/episode (weeks)	5–7	5–7
Right affected side	15 (50%)	15 (50%)
Left affected side	15 (50%)	15 (50%)
Dominant right hand	28 (93.3%)	28 (93.3%)
Dominant left hand	2 (6.67%)	2 (6.67%)
Dominant	15 (50%)	17 (56.7%)
Non-Dominant	15 (50%)	13 (43.3%)
TCT (points 48–61) ± SD	53.20 ± 6.31	53.63 ± 6.47
FMA-UE (points 43–49) ± SD	45.47 ± 1.87	45.50 ± 2.11
MAS (degrees 0/1/1+) (examined n)	0/1/1+ 0/20/10	0/1/1+ 0/20/10

2.3. Interventions

The research was carried out according to protocol no 4/KRN/2020, registered in Clinical Trial Registration.

Patients had physiotherapy at the Rehabilitation Clinic 6 days a week (Monday to Saturday). Patients were randomly allocated to Bobath or classical physiotherapy. The procedure in the study group was based on the use of the NDT Bobath concept. The aim of the exercises according to this concept is to gain torso control. Exercises were performed in closed kinematic chains, which helps to improve proprioception and stabilize and increase muscle tone. Exercises were conducted in various starting positions: lying on the back, on the sides, front, sitting, and supported kneeling, straight kneeling, and standing.

Therapy according to the NDT Bobath concept improves the daily functioning and structure of the patient's body by teaching various activities, such as sitting down, standing up, and various variants of walking. In turn, the treatment in the control group was based on the use of classic exercises, such as passive exercises. In order to relieve the directly affected limb, the patients exercised in the suspension system. As physiotherapy progressed, patients performed active exercises, and then active exercises with resistance, including with Thera Band. In addition, self-assisted exercises on the manual rotor. They also practiced their balance with large gym balls or sensory mats. Locomotion training and gait reeducation were a significant part of physiotherapy. The duration of a treatment session for each patient in both groups was 120 minutes.

Ethical approval of the study was received from the Ethical Committee of the Military Institute of Medicine in Warsaw, Poland (approval number 4/MIM/2020). Before inclusion, all subjects were informed about the purpose of the study. Written informed consent was obtained from all subjects by the tenets of the Declaration of Helsinki.

2.4. Apparatus and evaluation games used for examining

Armeo®Spring device (Hocoma AG, Switzerland) was used in the study. The main element of the device is an orthosis (exoskeleton) which has a system of springs supporting the exercised upper limb. The design of the device allows adjusting the orthosis to the patient. The adaptability of the device to the patient is ensured by the electrically adjustable column in the range of 400 mm, the length of the forearm in the range of 290–390 mm, the length of the arm in the range of 220–310 mm, the maximum weight of the forearm from 0.7 kg to 2.4 kg, the maximum weight of the arm from 0.5 kg to 3.8 kg. Armeo®Spring has 6 degrees of freedom (each with an independent motor and two sensors), thanks to which angular movements are possible in the range of: adduction/abduction in the shoulder joint: -169° to +50°, flexion/extension in the shoulder joint: +40° to +120°, internal/external shoulder rotation: 0° to 90°, elbow flexion/extension: 0° to 100°, forearm pronation/supination: -60° to +60°, wrist flexion/extension: -60° to +60°. In addition, the device has a pressure sensor for the grip. According to the manufacturer, the measuring accuracy of the device is < 0.2°.

Armeo®Spring is a professional tool for assessing the progress of therapy. The Armeo®Spring software enables the creation of patient databases, individualization of the therapy parameters for each patient, and modification of the levels of difficulty of exercises; moreover, it includes games and tasks to motivate the patient and provides transparent reporting. It has three diagnostic programs called evaluation games: "vertical fishing", "horizontal fishing", and "reaction time" [26].

2.4.1. Evaluation games

"Vertical Fishing" – the patient's task is to catch a ladybug. In this evaluation game, the patient has to move his hand in a vertical plane. When it touches the ladybug, the ladybug disappears and a new one appears elsewhere. If the patient does not touch the ladybug within the allotted time, the ladybug also disappears and another reappears elsewhere.

"Horizontal Fishing " – as in the previous game, the patient's task is to catch the red ball. In this evaluation game, the patient has to move his upper limb horizontally. The rules for the appearance and disappearance of an item are the same as in the previous game.

In both games, the patients were tested on the 1st level of difficulty, which means that the field of work was 40 × 30 cm and they had 12 objects to catch.

"Reaction time" – the patient moved their hand in the frontal plane to catch the fly. The rules of the game are the same as in the previous games, with the difference that each time the patient has to return to the center of the screen, to the shelf, and should remain on the shelf until another object appears on the screen. As in the previous games, the study was conducted on level I, with the working area of 30 × 26 cm, with the aim to catch 20 objects.

2.4.2. Armeo®Spring assessment parameters

The evaluation parameter used in the "vertical fishing" and "horizontal fishing" games is the hand movement path coefficient. It is used to assess the patient's quality of movement. This parameter was calculated by the quotient of the length of the trajectory of the patient's hand movement to the distance between the points that can be achieved in individual elements of the "vertical fishing" and "horizontal fishing" exercises. This ratio showed the extent to which the patient deviates from the shortest straight line connecting two objects when moving from one object to another. If the movement is perfect (the shortest in a straight line), the hand movement path coefficient is 1. If the coefficient is 3, it means that the patient's hand movement trajectory is three times longer than the shortest line that connects two objects.

The evaluation parameter used in the "reaction time" game is the measurement of the time taken for the patient to react. The software of the Armeo®Spring device measures the time from the moment the first object (a fly) appears on the screen to the moment it leaves the shelf, i.e. the starting base. Then the time is measured from the moment the fly disappears to the moment it returns to the shelf-base [26].

2.5. Tests used for examining

Apart from the Armeo®Spring device, two proprietary tests were used to examine the patients: "Abacus" and "Wall".

The "Wall" test consists in lifting the upper limb on one's own and moving it along the wall as high as possible. Patients performed it sitting straight with their knees pressed against the wall. Patients were scored according to the following schedule:

0 – the patient does not raise the upper limb
1 – the patient raises the upper limb to the shoulder height
2 – the patient raises the upper limb to the height of the head
3 – the patient raises the upper limb above the head

The purpose of the test was to assess the functional capabilities in the shoulder joint of the affected upper limb. This test examined whether the patient could overcome the force of gravity.

The "Abacus" test was performed on classic mathematical abacuses. The patient's task was to move the beads from one edge of the abacus to the other with two fingers (index and thumb) of the affected upper limb. The result of the test was the number of beads moved in 30 seconds. The test assessed the grasping activity of the upper limb (precise grip, according to Napier, pincer or paddle grip, apical grip) [27].

2.6. Sample size calculation

The sample size was estimated using the G*Power 3.1.9.4 program. Assuming the following parameters: effect size d = 0.59, $\alpha = 0.05$; Power = 0.8 for the Wilcoxon-Mann-Whitney test, the required sample size is 76 (38 people per group). Assuming that these parameters were met in the analyses, the adopted sample was sufficient.

2.7. Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 26.0. In order to compare the two groups, an analysis was performed with the Mann-Whitney U test. In order to compare the two measurements, analysis was performed with the Wilcoxon test. The level of significance was $\alpha = 0.05$.

3. Results

The results of this study can be analyzed in the order consistent with the following research questions:

1. Did the examined patients differ significantly before the therapy?
2. Which exercises substantially change the functional state of the affected dominant or nondominant upper limb in post-stroke patients?

3.1. Comparison of the results from the study and the control groups for the pre-treatment measurement

In order to compare the studied groups of patients before the exercises in the Mann-Whitney U test, the results of people randomly assigned to the study and control groups were compared. The conducted analysis did not show any significant differences between the study group (Table 3) and the control group (Table 4).

Table 3. Comparison of people from the study group with the dominant and non-dominant hands examined before the therapy

	Dominant (n = 17)			Non-Dominant (n = 13)			*Z*	*p*	*r*
	average rank	*Me*	*IQR*	average rank	*Me*	*IQR*			
Abacus [no of beads per 30 sec]	15.13	30.00	19.00	15.87	21.00	22.00	-0.23	0.819	0.04
Wall [no of points]	17.40	3.00	1.00	13.60	2.00	1.00	-1.31	0.191	0.24
Vertical fishing – task completion [%]	14.97	91.00	80.00	16.03	91.00	17.00	-0.35	0.729	0.06
Vertical fishing – time [s]	13.73	44.00	25.00	17.27	46.00	28.00	-1.10	0.271	0.20
Vertical fishing – hand movement path coefficient	13.47	1.80	0.42	17.53	2.00	0.68	-1.27	0.206	0.23
Horizontal fishing – task completion [%]	13.30	41.00	41.00	17.70	58.00	22.00	-1.37	0.170	0.25
Horizontal fishing – time [s]	16.20	87.00	45.00	14.80	80.00	23.00	-0.44	0.663	0.08
Horizontal fishing – hand movement path coefficient	12.60	1.99	0.68	18.40	2.33	1.53	-1.81	0.071	0.33
Reaction time – task execution [%]	15.00	100.00	0.00	16.00	100.00	0.00	-1.00	0.317	0.18
Reaction time – time [s]	13.90	149.00	48.00	17.10	156.00	43.00	-1.00	0.319	0.18

Legend: Me – median, IQR – quartile range, Z – standardized statistics of the Mann-Whitney U test, p – test probability, r – effect size.

Table 4. Comparison of people from the control group with the dominant and non-dominant hands examined before the therapy

	Dominant (n = 17)			Non-Dominant (n = 13)			*Z*	*p*	*r*
	average rank	*Me*	*IQR*	average rank	*Me*	*IQR*			
Abacus [no of beads per 30 sec]	16.94	23.00	9.00	13.62	22.00	11.00	-1.03	0.304	0.19
Wall [no of points]	13.38	2.00	2.00	18.27	3.00	1.50	-1.59	0.112	0.29
Vertical fishing – task completion [%]	15.18	90.00	33.50	15.92	78.00	32.50	-0.23	0.815	0.04
Vertical fishing – time [s]	15.18	60.00	57.50	15.92	68.00	61.00	-0.23	0.818	0.04
Vertical fishing – hand movement path coefficient	15.97	1.94	0.96	14.88	1.74	1.17	-0.33	0.738	0.06
Horizontal fishing – task completion [%]	17.65	55.00	29.00	12.69	41.00	25.00	-1.53	0.126	0.28
Horizontal fishing – time [s]	15.38	98.00	39.50	15.65	92.00	21.50	-0.08	0.933	0.02
Horizontal fishing – hand movement path coefficient	15.41	2.88	1.45	15.62	2.89	1.48	-0.06	0.950	0.01
Reaction time – task execution [%]	15.09	100.00	100.00	16.04	100.00	50.00	-0.38	0.702	0.07
Reaction time – time [s]	13.24	119.00	72.50	18.46	156.00	88.50	-1.61	0.107	0.29

Legend: Me – median, IQR – quartile range, Z – standardized statistics of the Mann-Whitney U test, p – test probability, r – effect size.

3.2. Comparison of test results for the dominant and non-dominant hand between the study and the control group, before and after the therapy

The Mann-Whitney U test was used to compare the applied therapies and to identify differences after the therapies for the examined dominant and non-dominant limbs. The calculations showed significant differences in both the study and the control group. At the same time, the analysis of the results speaks in favor of the dominant hand in the group rehabilitated according to the NDT Bobath concept (Tables 5 and 6).

Table 5. Comparison of the results of people from the study group and the control group, in whom the dominant hand was examined

	Study (n = 15)			Control (n = 13)			*Z*	*p*	*r*
	average rank	*Me*	*IQR*	average rank	*Me*	*IQR*			
Abacus [no of beads per 30 sec] Before	18.57	30.00	19.00	14.68	23.00	9.00	-1.17	0.241	0.21
Abacus [no of beads per 30 sec] After	20.50	41.00	28.00	12.97	29.00	9.00	-2.27	**0.023**	0.40
Wall [no of points] Before	20.23	3.00	1.00	13.21	2.00	2.00	-2.26	**0.024**	0.40
Wall [no of points] After	21.00	3.00	0.00	12.53	2.00	1.00	-3.06	**0.002**	0.54
Vertical fishing – task completion [%] Before	17.27	91.00	80.00	15.82	90.00	33.50	-0.44	0.657	0.08
Vertical fishing – task completion [%] After	18.93	100.00	0.00	14.35	100.00	7.00	-1.91	0.057	0.34
Vertical fishing – time [s] Before	12.13	44.00	25.00	20.35	60.00	57.50	-2.48	**0.013**	0.44
Vertical fishing – time [s] After	10.60	26.00	20.00	21.71	57.00	51.00	-3.35	**0.001**	0.59
Vertical fishing – hand movement path coefficient Before	14.83	1.80	0.42	17.97	1.94	0.96	-0.94	0.345	0.17
Vertical fishing – hand movement path coefficient After	13.87	1.53	0.75	18.82	1.67	0.60	-1.49	0.136	0.26
Horizontal fishing – task completion [%]Before	14.80	41.00	41.00	18.00	55.00	29.00	-0.96	0.335	0.17
Horizontal fishing – task completion [%] After	15.33	58.00	46.00	17.53	78.00	59.00	-0.67	0.505	0.12
Horizontal fishing – time [s] Before	14.53	87.00	45.00	18.24	98.00	39.50	-1.11	0.265	0.20
Horizontal fishing – time [s] After	14.80	82.00	39.00	18.00	89.00	31.50	-0.96	0.335	0.17
Horizontal fishing – hand movement path coefficient Before	12.60	1.99	0.68	19.94	2.88	1.45	-2.21	**0.027**	0.39
Horizontal fishing – hand movement path coefficient After	14.00	2.10	1.61	18.71	2.78	1.53	-1.42	0.157	0.25
Reaction time – task execution [%]Before	18.43	100.00	0.00	14.79	100.00	100.00	-1.62	0.105	0.29
Reaction time – task execution [%]After	18.50	100.00	0.00	14.74	100.00	50.00	-1.98	**0.048**	0.35
Reaction time – time [s] Before	18.93	149.00	48.00	14.35	119.00	72.50	-1.38	0.168	0.24
Reaction time – time [s] After	19.17	120.00	20.00	14.15	100.00	52.50	-1.51	0.131	0.27

Legend: Me – median, IQR – quartile range, Z – standardized statistics of the Mann-Whitney U test, p – test probability, r – effect size.

Table 6. Comparison of the results of the study group and the control group, in whom the non-dominant hand was examined

	Study (n = 15)			Control (n = 13)			*Z*	*p*	*r*
	average rank	*Me*	*IQR*	average rank	*Me*	*IQR*			
Abacus [no of beads per 30 sec] Before	15.93	21.00	22.00	12.85	22.00	11.00	-0.99	0.322	0.19
Abacus [no of beads per 30 sec] After	19.53	45.00	17.00	8.69	24.00	17.00	-3.48	**0.001**	0.66
Wall [no of points] Before	13.60	2.00	1.00	15.54	3.00	1.50	-0.68	0.499	0.13
Wall [no of points] After	15.20	3.00	0.00	13.69	3.00	1.00	-0.64	0.519	0.12
Vertical fishing – task completion [%] Before	15.90	91.00	17.00	12.88	78.00	32.50	-1.00	0.318	0.19
Vertical fishing – task completion [%] After	15.97	100.00	9.00	12.81	100.00	15.50	-1.19	0.235	0.22
Vertical fishing – time [s] Before	12.17	46.00	28.00	17.19	68.00	61.00	-1.61	0.107	0.30
Vertical fishing – time [s] After	11.30	32.00	18.00	18.19	47.00	56.00	-2.21	**0.027**	0.42
Vertical fishing – hand movement path coefficient Before	15.83	2.00	0.68	12.96	1.74	1.17	-0.92	0.357	0.17
Vertical fishing – hand movement path coefficient After	14.07	1.62	0.76	15.00	1.54	0.90	-0.30	0.764	0.06
Horizontal fishing – task completion [%]Before	17.50	58.00	22.00	11.04	41.00	25.00	-2.08	**0.037**	0.39
Horizontal fishing – task completion [%] After	15.83	66.00	59.00	12.96	53.00	36.50	-0.93	0.353	0.18
Horizontal fishing – time [s] Before	11.03	80.00	23.00	18.50	92.00	21.50	-2.40	**0.017**	0.45
Horizontal fishing – time [s] After	13.77	83.00	37.00	15.35	80.00	35.00	-0.51	0.612	0.10
Horizontal fishing – hand movement path coefficient Before	13.80	2.33	1.53	15.31	2.89	1.48	-0.48	0.628	0.09
Horizontal fishing – hand movement path coefficient After	13.70	2.04	2.06	15.42	2.20	1.56	-0.55	0.580	0.10
Reaction time – task execution [%]Before	16.00	100.00	0.00	12.77	100.00	50.00	-1.93	0.053	0.37
Reaction time – task execution [%]After	15.50	100.00	0.00	13.35	100.00	0.00	-1.55	0.122	0.29
Reaction time – time [s] Before	15.00	156.00	43.00	13.92	156.00	88.50	-0.35	0.729	0.07
Reaction time – time [s] After	15.10	127.00	35.00	13.81	117.00	71.00	-0.41	0.678	0.08

Legend: Me – median, IQR – quartile range, Z – standardized statistics of the Mann-Whitney U test, p – test probability, r – effect size.

4. Discussion

The results of this study showed that the NDT Bobath therapy is important for the functional improvement of the affected upper limb in patients after stroke in the acute phase of the disease. Moreover, more significant results were obtained after the therapy with regard to the dominant limb. The results of the research are emphasized by the fact that the analysis of the parameters before the start of the therapy did not show any significant differences for the dominant and non-dominant limb, both in the study group and in the control group. Moreover, in the test and control groups, no significant differences were found between the dominant and non-dominant hands, also after the therapy. Significant differences appeared as a result of the applied therapies, using both NDT Bobath and classic exercises, both for the dominant and non-dominant limbs. The results revealed a significant advantage in both cases after each treatment, compared to the results from before the treatment.

Additional analysis of dominant limbs (Table 5) and non-dominant limbs (Table 6) in the study and control groups before and after therapy showed that the dominant limb obtained two significantly higher results (wall test and vertical fishing time) in the study group (NDT Bobath), both before and after therapy. The results in the abacus test and reaction time - [%] of task completion were significant only after therapy. The analysis of the non-dominant limb showed an advantage in four parameters, and this significance concerned the results only after therapy according to NDT Bobath. Taking into account that after NDT Bobath therapy, we obtained four significantly higher results for the non-dominant limb and only two for the dominant limb, we recognize the advantage of trunk stabilization therapy for the non-dominant limb.

In this study, functional examination of the upper limb was carried out, among others, with the use of the Armeo®Spring device, which, in addition to evaluation games, includes many games for everyday training of the upper limbs. It is a modern device from the Armeo® family, used to diagnose ranges of motion and coordination of the upper limb and also used in neurorehabilitation. Physiotherapy consists in working with an orthosis, a spring system which supports the rehabilitated upper limb and can support training. The brace is intended for patients with limited or lost shoulder functionality [26]. Armeo®Spring was used by Gueye et al. [28] for working with elderly patients after stroke, as well as by Gijbels et al. [29] in the physiotherapy of children with cerebral palsy. In turn, Colomer et al. [30] presented the use of this device in the improvement of the upper limb in patients after stroke at the early stage, and Adomavičienė et al. [31] compared the applications of Armeo®Spring and Kinetic Kontrol. In our case, this is our second study in which we used this device for the functional examination of the upper limb [32].

As this research shows, both applied therapies bring significant improvement, both in the case of the affected dominant and non-dominant limb. The comparison of the results between the groups, however, reveals that more significant results can be obtained after the NDT Bobath concept for the affected non-dominant upper limb.

Armstrong et al. [33] compared the strength of the dominant and non-dominant hand in right-handed and left-handed people. In all tests, there were no significant differences between the hands of left-handed people and slight but significant differences between the hands of right-handed people. They also noted that there was considerable variation in the relative strength of both hands for each participant. In turn, Xiang et al. [34] proved in their research that dominant hand movements and/or vigorous movements were more effective with a straighter hand path and less torso rotation, and conversely, dominant hand movements were less effective with fast movements. Many researchers believe that upper limb rehabilitation exercises after a stroke should cover the non-dominant arm in addition to the dominant upper limb [35, 36]. Therapists should strive to maintain and restore nearly equal grip strength scores between the dominant and non-dominant hands to ensure better hand function [37, 38]. Moreover, many researchers confirm the effectiveness of exercises aimed at a stable torso. Based on their research, Lee et al. [39] recommend torso stabilization exercises as part of a post-hospital exercise in stroke patients. They examined 46 patients, 6 months after the stroke. The first group exercised the upper limbs with symmetrical contraction of the abdominal muscles, the second group exercised the upper limbs without the abdominal muscles. They found that in the study group there was a significant improvement in balance. The results of research by Hodge and Richardson [40] confirmed that exercises stabilizing the trunk by working on the deep abdominal muscles more effectively increase the range and fluidity of limb movement than other forms of exercise. Other researchers also prove the importance of the tension of the muscles that deeply stabilize the trunk for the work of the lower limbs and coordinated movements of the torso [41].

To sum up, the treatment of patients after a stroke in the acute phase of the disease, both aimed at improving the stability of the trunk and classic exercises, significantly affect the functional improvement of the affected dominant and non-dominant upper limb; however, exercises according to NDT Bobath are of greater importance and we notice this improvement, especially in the case of the affected non-dominant upper limb.

Research Value

Physiotherapy of a patient after a stroke, including exercises aimed at improving the stability of the trunk, has a significant impact on increasing the functional efficiency of the affected upper limb and on improving the grasping of the hand and should be included in the rehabilitation program of patients after a stroke.

Study Limitation

A limitation in our work is the relatively short time of therapy between the first and second examinations. Moreover, the objectivity of the results could have been influenced by a smaller group of test persons than indicated by the sample calculation. Moreover, taking into account the purpose of the work, the methodology of measurements on the Armeo®Spring device may also be a limitation of this study. The instructions for use assume that the patient is in a sitting position with back support. This support stabilizes the trunk, and the goal of this study was to check how the NDT Bobath trunk stabilization exercises change the functionality of the upper limb. It seems that it would be better to examine patients without support before and after therapy or to perform the examination twice before and twice after the applied therapies (with and without back support). Subsequent studies will take into account the above-mentioned limitations of the current study.

5. Conclusions

Physiotherapy, according to the NDT Bobath concept, has a significant impact on the functional improvement of the affected non-dominant upper limb.

Exercises to improve the stability of the trunk should be included in the rehabilitation program of patients after stroke already in the acute phase of the disease.

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Author Contributions: Study Design, AO; Data Collection, AO; Statistical Analysis, AO; Data Interpretation, AO and MD; Manuscript Preparation, AO and MD; Literature Search, AO and MD; Funding Acquisition, AO. All authors have read and agreed to the published version of the manuscript.

Acknowledgements: Not applicable.

Funding: This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Clinical Trial Registration-URL: http://www.clinicaltrials.gov. Unique identifier: NCT05365945.

Institutional Review Board Statement: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical review committee statement of Commission of Ethics of the Ethical Committee of the Military Institute of Medicine (MIM); (approval number 4/MIM/2020).

Informed Consent Statement: Informed consent was obtained from all individual adult participants included in the study. Written informed consent was obtained from all subjects in accordance with the tenets of the Declaration of Helsinki.

Data Availability Statement: Data available from the corresponding author on request.

Conflicts of Interest: The authors declare no conflict of interest.