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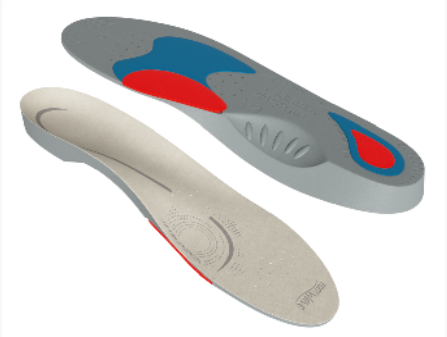

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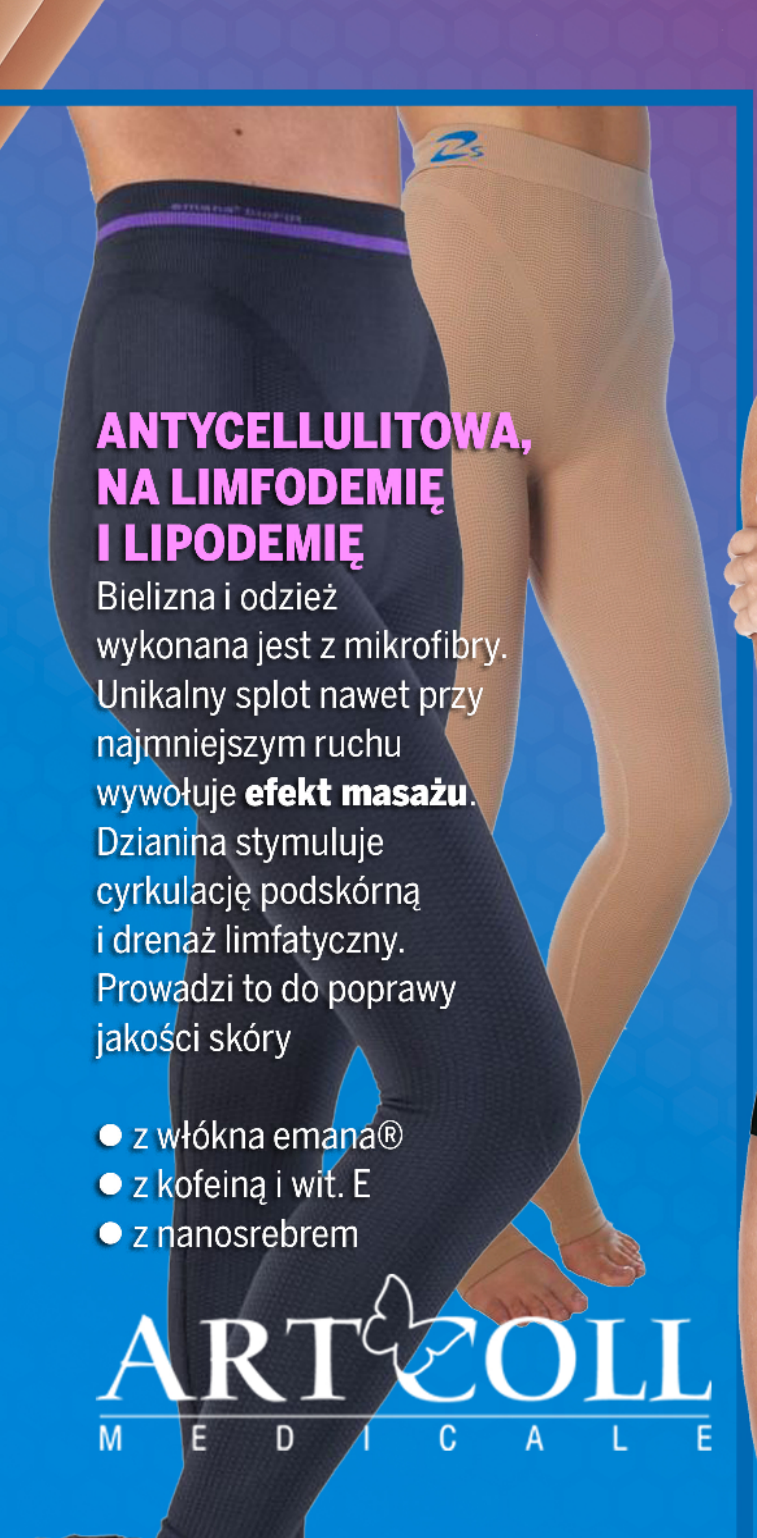

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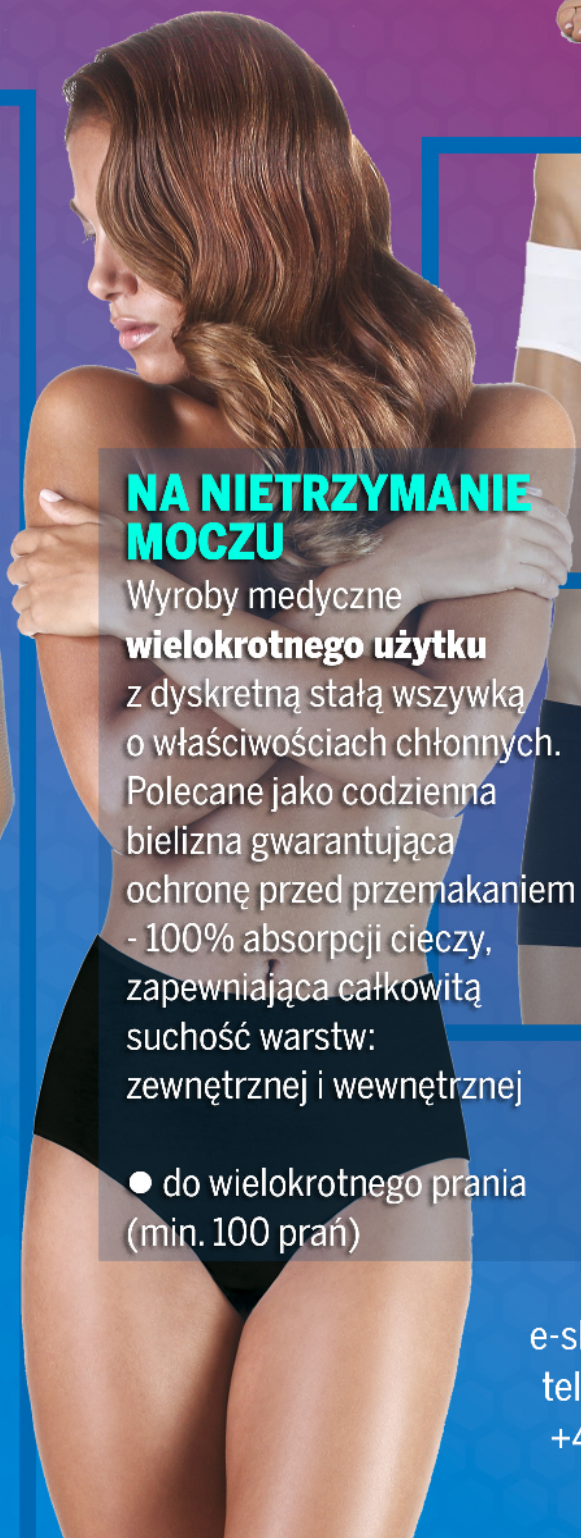

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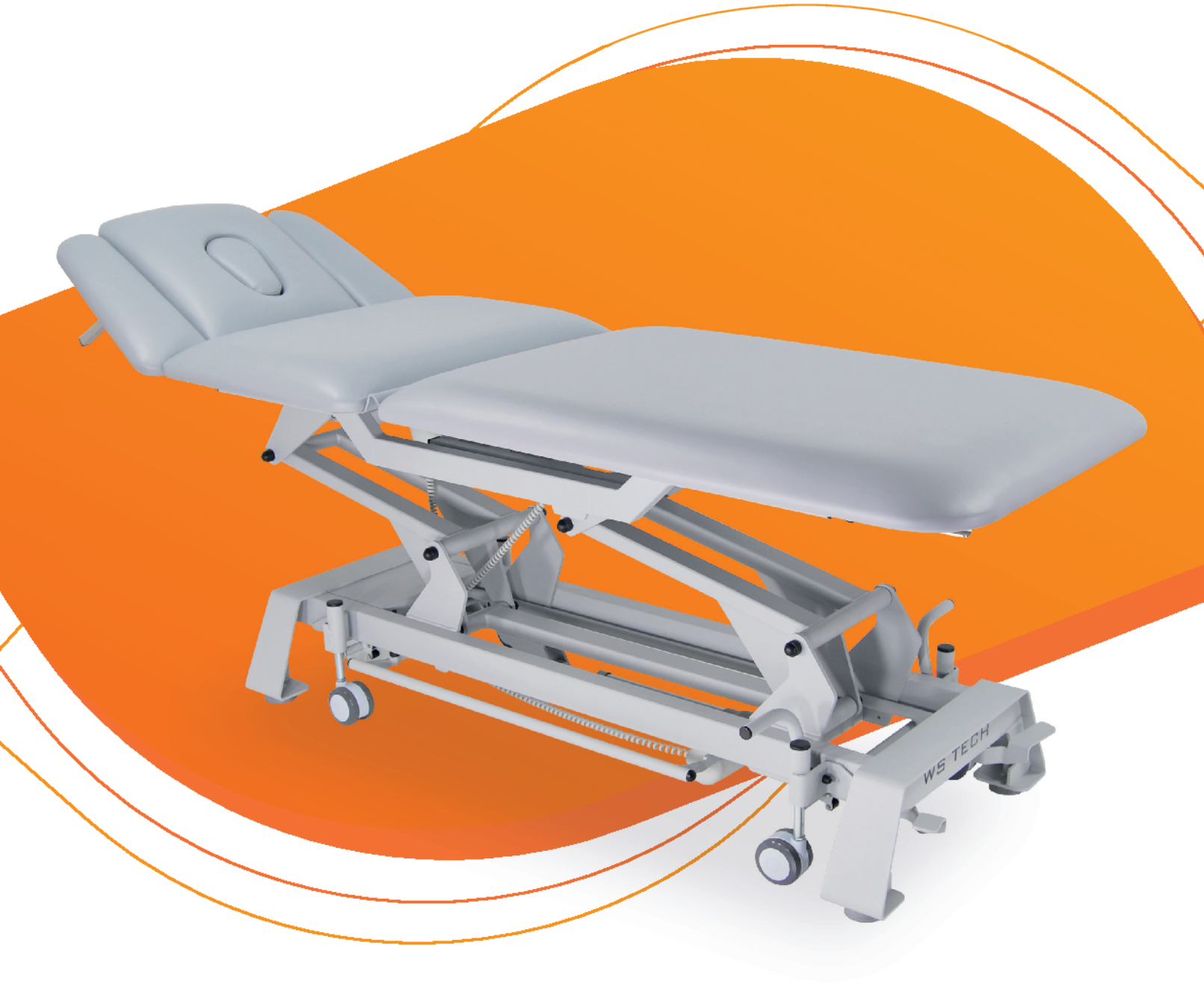

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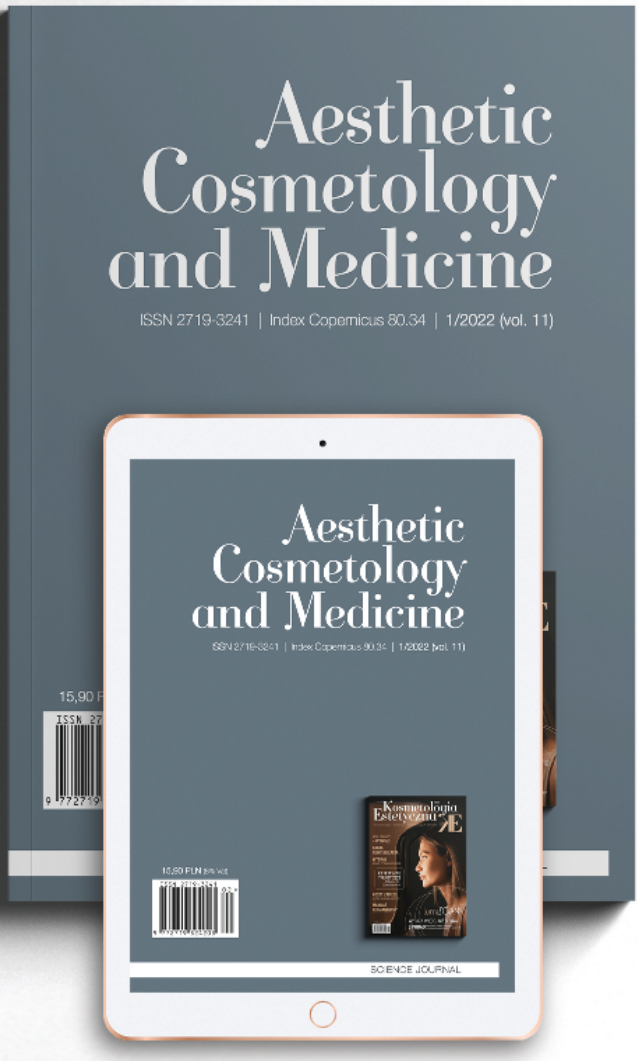

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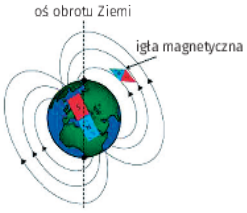

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The impact of comprehensive spa treatment with the use of a stabilometric platform on postural balance control and functional fitness of patients after a stroke

Wpływ kompleksowego leczenia uzdrowiskowego z wykorzystaniem platformy stabilometrycznej na kontrolę równowagi ciała i sprawność funkcjonalną pacjentów po udarze mózgu

Agnieszka Nitera-Kowalik[1,2(A,C,D,E,F)], Iwona Sarzyńska-Długosz[3(A,C,D,E)], Małgorzata Łukowicz[4(A,G)], Agnieszka Malec[1(B,E,F)], Robert Owsiński[1(B,E,F)], Wiesław Bujalski[1(A,B,E)]

[1]21 Wojskowy Szpital Uzdrowiskowo-Rehabilitacyjny w Busku-Zdroju / 21st Military Spa and Rehabilitation Hospital in Busko-Zdrój, Poland
[2]Collegium Medicum, Instytut Nauk o Zdrowiu Uniwersytet Jana Kochanowskiego, Kielce / Collegium Medicum, Institute of Health Sciences, Jan Kochanowski University of Kielce, Poland
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[4]Klinika Rehabilitacji CMKP w Otwocku / Rehabilitation Clinic of CMKP in Otwock, Poland

Abstract

Introduction. Loss of postural balance control is a symptom that occurs in 60% of stroke patients, limiting patients' mobility and functional efficiency. The reconstruction of lost functions can be achieved thanks to comprehensive spa treatment with the use of a modern device for the assessment and training of balance - a stabilometric platform.

The objective was to assess the impact of comprehensive spa treatment, including therapy on a stabilometric platform, on balance and functional fitness of stroke patients undergoing rehabilitation at the 21st Military Spa and Rehabilitation Hospital in Busko-Zdrój.

Material and methods. Seventeen patients were examined: 6 patients (35.3%) after a haemorrhagic stroke and 11 patients (64.7%) after an ischemic stroke diagnosed according to ICD-10: I.69, G.81; including 4 (23.5%) women and 13 (76.5%) men. Patients in the study group aged 35 to 70 (58.06 on average) received spa and rehabilitation treatment at the 21st Military Spa and Rehabilitation Hospital in Busko-Zdrój. The examinations were carried out from May 2019 to October 2020 as part of the project "Establishing a research laboratory for methods of rehabilitation of patients with musculoskeletal disorders". The patients were subject to a comprehensive spa treatment program, extended with objective assessment and exercises on the Alfa stabilometric platform. Selected tests and clinical scales were used for the functional assessment of patients: Timed Up and Go test (TUG test), 10-meter walk test (10 Meter Walk Test), 2-minute walk test (2MWT). The patients were assessed on the day of commencing the spa treatment and after three weeks.

Results. Objective improvement of balance parameters in the stabilometric evaluation after 3 weeks of spa and rehabilitation treatment was noticed in the younger group of patients with right hemiparesis long after a stroke. Patients with left hemiparesis achieved shorter task completion times in the 10MWT and TUG clinical tests. In addition, they covered a longer distance in the 2MWT test.

Conclusions. The program of comprehensive spa and rehabilitation treatment, enriched with training with the use of the Alpha stabilometric platform, had a positive effect on the improvement of balance parameters and gait function in patients long after a stroke. Therapy on a stabilometric platform with the use of biofeedback should be a standard element of therapy in stroke patients.

Key words:
spa treatment, stroke, stabilometric platform

Streszczenie

Wstęp. Utrata kontroli nad równowagą posturalną jest objawem, który występuje u 60% pacjentów po udarze mózgu, ograniczając zdolność do lokomocji i sprawność funkcjonalną chorych. Odbudowę utraconych funkcji można uzyskiwać dzięki kompleksowemu leczeniu uzdrowiskowemu z wykorzystaniem nowoczesnego urządzenia do oceny i treningu równowagi – platformy stabilometrycznej.

Celem pracy była ocena wpływu kompleksowego leczenia uzdrowiskowego z uwzględnieniem terapii na platformie stabilometrycznej na równowagę i sprawność funkcjonalną pacjentów po udarze mózgu przebywających na leczeniu rehabilitacyjnym w 21 Wojskowym Szpitalu Uzdrowiskowo-Rehabilitacyjnym w Busku-Zdroju.

Materiał i metody. Badaniu poddano 17 chorych: po udarze krwotocznym mózgu 6 osób (35,3%) i po udarze niedokrwiennym – 11 osób (64,7%) z rozpoznaniem wg ICD-10: I.69, G.81; w tym 4 (23,5%) kobiety i 13 (76,5%) mężczyzn. Pacjenci badanej grupy w wieku od 35 do 70 lat (średnio 58,06 lat) korzystali z leczenia uzdrowiskowo-rehabilitacyjnego w 21 Wojskowym Szpitalu Uzdrowiskowo-Rehabilitacyjnym w Busku-Zdroju. Badania prowadzono od maja 2019 do października 2020 w ramach projektu „Utworzenie laboratorium badawczego metod rehabilitacji pacjentów z dysfunkcjami narządu ruchu". Badani realizowali kompleksowy program leczenia uzdrowiskowego, rozszerzony o obiektywną ocenę i ćwiczenia na platformie stabilometrycznej Alfa. Do oceny funkcjonalnej pacjentów zastosowano wybrane testy i skale kliniczne: test Wstań i Idź (test Timed Up and Go – TUG), 10-metrowy test chodu (10 Meter Walk Test), 2-minutowy test chodu (2 Minute Walk Test – 2MWT). Oceny badanych dokonano w dniu rozpoczęcia i po okresie 3 tygodni leczenia uzdrowiskowego.

Wyniki. Obiektywną poprawę parametrów równowagi w ocenie stabilometrycznej po 3 tygodniach leczenia uzdrowiskowo-rehabilitacyjnego zauważono w młodszej grupie pacjentów z niedowładem prawostronnym po udarze mózgu w czasie odległym od zachorowania. Krótszy czas wykonania zadania w testach klinicznych 10MWT, TUG osiągnęli pacjenci z niedowładem lewostronnym. Ponadto przeszli dłuższy dystans w 2MWT.

Wnioski. Program kompleksowego leczenia uzdrowiskowo-rehabilitacyjnego, wzbogacony o trening z wykorzystaniem platformy stabilometrycznej Alfa, wpłynął korzystnie na poprawę parametrów równowagi i funkcję chodu u pacjentów po udarze mózgu w czasie odległym od zachorowania. Terapia na platformie stabilometrycznej z wykorzystaniem biologicznego sprzężenia zwrotnego powinna być standardowym elementem terapii u osób po przebytym udarze mózgu.

Słowa kluczowe:
leczenie uzdrowiskowe, udar, platforma stabilometryczna

Introduction

Stroke is the most common damage to the nervous system, and according to WHO it is the second most common cause of death (11.8% – 6.5 million of all deaths) and the number one cause of disability in 25-50% of middle-aged patients (over 40 years of age). Every year, 10.3 million people worldwide experience a stroke (in Poland – about 80,000/ year), and 2/3 of all strokes affect people under 70 [1].

The area of damage to the central nervous system (CNS) is due to the pathogenesis and location of the stroke focus. It can be a consequence of insufficient blood supply to certain parts of the brain, retina or spinal cord as in the case of an ischemic stroke (80-90% of stroke cases) or it occurs as a result of blood extravasation to the brain and/or subarachnoid space as a result of arterial rupture in the case of a haemorrhagic stroke (10–20% of cases). A stroke results in motor deficits - primarily hemiparesis (48% of people), problems with maintaining balance and locomotion (22% of people), which may persist even for the rest of the patients' lives, as well as cognitive disorders, including attention disorders and visual-spatial disturbances, which additionally make it difficult to regain the ability to walk independently. Between 24% and 53% of stroke survivors require assistance with basic activities of daily living (ADL). The severity of a stroke and its dominant symptoms determine the possibility of regaining postural balance control and the ability to move independently. Motor disturbances influence the appearance of adaptive compensations. Incorrect muscle tension on one side of the body causes uneven pressure of the lower limbs on the ground and asymmetry in body posture. As a result, the ability to control the centre of gravity of the body is diminished, which negatively affects balance responses and makes it difficult to control one's posture. As a consequence, the risk of falling increases [2, 3, 4].

The overriding goal of post-stroke rehabilitation of patients is to restore the lost function to the maximum possible extent, including restoration of balance reactions and improvement of the patients' quality of life. The measure of the effectiveness of rehabilitation of patients with hemiparesis after a stroke is restoring correct postural reactions, achieving independence or maximum independence in terms of gait functions, basic and complex activities of daily living.

Comprehensive spa rehabilitation, including training on a stabilometric platform, enables the achievement of the set goals. Platform therapy, based on the phenomenon of biofeedback, aims to stimulate the elements of the musculoskeletal and nervous systems, for example responsible for balance control. The central nervous system, which plays a superior role in this process, receives and analyses the stimuli coming from proprioreceptors [5]. The central nervous system, thanks to the mechanisms of brain plasticity, has the ability to learn and adapt, which can be intensified by exercise [6].

The visual-motor stimulation, in which biofeedback is activated, contributes to the creation of new synaptic connections, which brings back the lost CNS functions [7].

During the therapeutic session, the patient performs training tasks, stimulating the side affected by paresis, activating proprioreceptors located in tendons, muscles, ligaments, joints and bones, learns to evenly load the "unaffected" and "affected" side. Proprioreceptors transmit information from these structures about the position of individual parts of the body to the CNS, initiating reflex reactions. Patients who use therapy with stabilometric platforms for a longer period of time begin to load both lower limbs more evenly, their stability, coordination and accuracy of performed tasks improve [8].

Objective

The objective is to assess the impact of comprehensive spa treatment, including therapy on a stabilometric platform, on balance and functional fitness of patients long after a stroke, undergoing rehabilitation treatment at the 21st Military Spa and Rehabilitation Hospital in Busko-Zdrój.

Material and methods

The study included seventeen patients after a stroke: 6 (35.3%) patients suffered a haemorrhagic stroke and 11 (64.7%) patients an ischemic stroke, including 4 (23.5%) women and 13 (76.5%) men – patients of the 21st Military Spa and Rehabilitation Hospital in Busko-Zdrój. In 6 patients (35.3%) the left side was affected, while in 11 (64.7%) the paresis affected the right side. The average age of the patients was 58.06 ± 10.2 years. The youngest patient was 35 years old and the oldest was 70 years old. Among the patients with left hemiparesis, the average age of patients was 63.17, the youngest subject was 52 years old, the oldest was 70 years old. Patients with right hemiparesis constituted a younger age group, the average age was 55.27, the youngest patient was 35 and the oldest was 69 years old. The time since the stroke occurred ranged from 1 to 21 years. The largest number of patients suffered a stroke from 1 to 5 years ago – 8 patients (47.1%), between 6 and 10 years ago – 4 patients (23.5%), and over 10 years ago – 5 patients (29.4%).

The study was carried out as part of the project "Establishing a research laboratory for methods of rehabilitation of patients with musculoskeletal disorders", carried out in the period from May 2019 to October 2020. The comprehensive spa treatment program included balneotherapy treatments (sulphide-hydrogen sulphide salt baths, dry carbonic acid bath), hydrotherapy (underwater massage, whirlpool massage of lower limbs and upper limbs), physical therapy (laser, local cryotherapy, medium and low frequency currents, classic massage and dry hydro massage) and kinesiotherapy (individual, neurological – using PNF method and general rehabilitation in a rehabilitation pool). Treatments were applied daily or every other day from Monday to Saturday (six days a week). In addition, all patients underwent a therapy program on the Alfa stabilometric platform (Technomex, Poland), aimed at improving the gait function, balance, symmetry of the load on the lower limbs and precision of movements. Trainings in the form of programmed games focused on improving the functioning of the neuromuscular

system and hand-eye coordination. The therapy program is divided into three stages with a progressively increasing degree of difficulty. After the training, the accuracy, precision of movements and divisibility of attention were assessed. The criterion for moving to the next stage was to obtain 60% correctness of the task performed in all games of the previous stage. The patient's unit therapy time was 15 minutes and included 4 games, 90 seconds each, once a day and was carried out every day except for Sundays (six days a week). Static tests of postural control on the Alfa stabilometric platform equipped with VAST (Rehab software), enabling the assessment of postural control and data collection, included the assessment of the patients' balance in a free standing position with eyes open (no image control on the monitor) and eyes closed. Each test lasted 30 seconds. The analysis covered the length of the foot centre of pressure (COP) path in cm, the distribution of loads on the lower right and left limbs expressed as a percentage, deviation from the X and Y axes (with eyes open and closed) in cm, COP surface area (with eyes open and closed) in cm^2, the speed of bending in the X and Y axes (with eyes open and closed) in cm/s. After assuming a standing position, the patient's task was to keep the body in balance for 30 seconds. The load on the right and left lower limbs was analysed as a percentage.

During the examination and training, the patient's feet were placed on the platform at the width of the pelvis in such a way that the point visible on the monitor was at the intersection of the X and Y coordinates, and the ankles were on a line perpendicular to the axis dividing the platform into two halves (right and left). All tests were performed under the same conditions. The tests were performed twice before treatment and after 3 weeks of treatment.

For the functional assessment of patients, the following were used: Timed Up and Go Test (TUG), 10-meter walk test, 2-minute walk test (2MWT). The patients were assessed on the day of commencement and completion of spa rehabilitation. The TUG test was used to assess gait and fall risk. At the instruction "go", the patient was to get up from the chair and at his/her usual, safe pace, cover the designated distance, cross the line ending the designated distance and make a 180-degree turn, return to the chair and assume the sitting position again. The assessment involved maintaining balance while walking and the duration of the task, the need to support oneself with the hands when standing up or sitting down, equal length of steps, balance of the upper limbs, smooth rotation and any stops. The results were interpreted as follows: <10 seconds - normal functional fitness (low risk of falls), 10-19 seconds - the patient can go outside on their own, does not need any auxiliary walking equipment, independent in most activities of daily living, detailed assessment of the risk of falls (medium risk of falls) is recommended, ≥ 19 seconds (high risk of falls) - significantly limited functional capacity, cannot go outside alone, recommended auxiliary equipment for walking, requires assistance with almost any activity of daily living [9].

A 10-meter walk test was used to assess functional fitness of the patients in terms of walking, analysing its speed. During

the test, the patient walked 10 meters without the active help of other people. The time was measured for intermediate 6 meters, i.e. from the 2nd meter to the 8th meter (to ignore acceleration and deceleration). The patient could use individual orthopaedic equipment and auxiliary devices - the type of orth
opaedic equipment used had to be the same during each test. Time was measured when the toes of the front foot crossed the 2-meter mark. The stopwatch was stopped when the toes of the back foot crossed the 8-meter distance mark. The test was performed twice: at a natural pace and quickly [10].
The interpretation was made as follows:

Age [years]	Average walking speed [m/s]	
	Men	Women
20–29	1.36	1.34
30–39	1.43	1.34
40–49	1.43	1.39
50–59	1.43	1.31
60–69	1.34	1.24
70–79	1.26	1.13
80–99	0.97	0.94

Another test to assess mobility was the 2MTW test, assessing the distance that could be covered. Before starting the test, the patient rested in a sitting position for 10 minutes, and up to 2 hours prior to the test the patient did not eat a large meal and did not perform vigorous exercise. Initial measurements of blood pressure, pulse and saturation were performed prior to the test. The patient walked at his/her own pace, he/she was not allowed to run, but he/she could slow down or stop during the test. Rest breaks without stopping the timer were allowed if necessary. The aim of the test was to cover the longest distance possible within the prescribed time of 2 minutes. After the 2 minutes, blood pressure, pulse and saturation were measured again.
In the initial examination, the patients underwent functional tests assessing their degree of independence in activities of daily living (ADL), gait function and mobility. For this purpose, the following were used: the Katz ADL Index, the Barthel scale, the Functional Ambulation Classification (FAC), and the Rivermead Mobility Index (RMI). In addition, the Scandinavian Stroke Scale (SSS) was used to assess the existing neurological disorders.
The ability of patients to function independently in performing basic activities of daily living, such as: dressing, eating, using the toilet, defecation control with division into stool and urine, and patient mobility at home was assessed using the Katz Basic ADL Index [10]. The degree of independence of the patients was determined on the basis of the points obtained: 5–6 points – a fit person (fully maintained and controlled activities), 3-4 points – moderately functional (moderate degree of functional impairment), ≤ 2 severe disability (severe functional impairment).
The Barthel scale [11] assessed the mobility of patients in terms of 10 basic activities of daily living: eating, personal hygiene, dressing, changing position and moving, sphincter con-

trol, using the toilet. The degree of independence was determined on the basis of the points obtained: 86–100 points – the patient's condition is not severe, 21–85 points – the patient's condition is severe, 0–20 points – the patient's condition is very severe.
Functional gait assessment was used to assess the degree of independence of patients when walking [10]. The patients' ability to move was determined according to categories 0 to 5 – table 1.

Table 1. Functional Ambulation Classification – FAC [10]

Category 0	Patient does not walk or non-functional gait – walks only using handrails with the help of two people
Category 1	Walking dependant on substantial physical help from another person to maintain body weight control and balance
Category 2	Walking dependent on continuous or intermittent light physical assistance from another person to maintain balance and coordination
Category 3	Walking under verbal supervision or with passive belay
Category 4	Walking independently only on smooth, flat surfaces, requires assistance on uneven surfaces, slopes and stairs
Category 5	Walking completely independently on all surfaces

The patients' mobility (e.g. changing positions, transfers) and locomotion (e.g. walking on flat surfaces, walking on stairs), a total of 15 points, were assessed on a 6-point scale (from 0 to 5 points) using the Rivermead Mobility Index (RMI) [10]. The patients could get a maximum of 75 points.
1. Turning from side to side within the bed.
2. Changing from a lying to a sitting position.
3. Maintaining balance in a sitting position.
4. Changing from a sitting position to a standing position.
5. Standing without support.
6. Moving from bed to chair and back.
7. Walking around the house with help.
8. Walking up/down the stairs.
9. Walking outside on an even surface.
10. Walking at home without assistance.
11. Lifting objects from the floor.
12. Walking outside on all surfaces.
13. Bathing (getting in and out of the tub/shower).
14. Going up and down the stairs.
15. Running.

In the Scandinavian stroke scale, the neurological condition of patients was assessed by assigning points to individual parameters: consciousness (0–6 points), eye movements (0-4 points), orientation (0–6 points), speech – aphasic disorders (0–10 points), paresis of the facial nerve (0–2 points), degree of muscle paresis: arm (0-6 points), hand (0–6 points), lower limb (0–6 points) and gait (0-12 points). The total SSS score ranged from 0 to 58 points. [11].
The calculations were made with the use of the SOFA statistical package and the Excel spreadsheet. Quantitative

variables were characterized by basic descriptive measures: mean and standard deviation (SD), the minimum and maximum value (min-max), median (Me). In the case of qualitative variables, the number of observations (N) and the corresponding percentage (%) were given. Student's t-test was used to compare the results before and after the spa and rehabilitation treatment in the case of quantitative variables. The value of the p parameter in the Student's t-test is lower than the assumed statistical significance level of $p = 0.05$ for most functional tests.

Results

In terms of the ability to perform basic activities of daily living, using the Katz Basic ADL Index (Table 2), 94.1% of the patients obtained 5-6 points, which means a person who is efficient and independent in everyday functioning. Among patients with left hemiparesis it was 100% of the group, and 90.9% in the case of patients with right hemiparesis. Only 1 examined patient, 9.1% in the group with right hemiparesis, scored 3-4 points, qualifying as a moderately disabled person. In the study group, there were no patients who were significantly disabled (1–2 points) according to the Katz index of basic activities of daily living.

Table 2. Patients in the context of the assessment of fitness in the Katz Scale

	Total		Left hemiparesis		Right hemiparesis	
	N	%	N	%	N	%
fit patient 5–6 points	16	94.1%	6	100.0%	10	90.9%
moderately disabled patient 3–4 points	1	5.9%	0	0.0%	1	9.1%
Significant disability ≤ 2	0	0.0%	0	0.0%	0	0.0%

In the assessment of the degree of independence of the patients' gait according to the FAC index (Table 3), 70.6% of the patients were classified as category 4 – independent walking only on even surfaces, require assistance on an uneven slope and on stairs. Among the patients with right hemiparesis it was 63.6%, and 83.3% with left hemiparesis. 23.5% of the patients were classified as category 5 after the examination – walking completely independently on all surfaces. In this group, 27.3% of respondents were patients with right hemiparesis and 16.7% with left hemiparesis. None of the patients with left hemiparesis were assigned to categories 3, 2, 1, 0 according to the FAC index. One patient with right hemiparesis (9.1%) was classified as category 2 – walking dependent on a little physical assistance in order to maintain balance.

Table 3. Patients in the context of the assessment of fitness in the FAC Scale

	Total		Left hemiparesis		Right hemiparesis	
	N	%	N	%	N	%
Category 0 – non-functional gait, walking only using handrails with the help of two people	0	0.0%	0	0.0%	0	0.0%
Category 1 – walking dependent on substantial physical assistance from another person (Level II)	0	0.0%	0	0.0%	0	0.0%
Category 2 – walking dependent on a little physical assistance to maintain balance (Level I)	1	5.9%	0	0.0%	1	9.1%
Category 3 – supervised walking	0	0.0%	0	0.0%	0	0.0%
Category 4 – independent walking only on even surfaces, require assistance on uneven slopes and stairs	12	70.6%	5	83.3%	7	63.6%
Category 5 – walking completely independently, on all surfaces	4	23.5%	1	16.7%	3	27.3%

As assessed by the Barthel index (Table 4), the condition of 58.8% of the patients was assessed as moderately severe. This group included 72.7% of patients with right hemiparesis and 33.3% of patients with left hemiparesis. The condition of 41.2% was defined according to this scale as not severe in terms of independence in performing activities of daily living. This group included 66.7% of patients with left hemiparesis and 27.3% of patients with right hemiparesis. None of the patients' condition was described as very severe.

Table 4. Patients in the context of the assessment of fitness in the Barthel Scale

	Total		Left hemiparesis		Right hemiparesis	
	N	%	N	%	N	%
I 86–100 points, patient's condition – not severe	7	41.2%	4	66.7%	3	27.3%
II 21–85 points, patient's condition – moderately severe	10	58.8%	2	33.3%	8	72.7%
III 0–20 points, patient's condition – very severe	0	0.0%	0	0.0%	0	0.0%

Assessment of patients using the Rivermead Mobility Index (Table 5) showed that 35.3% of the patients obtained 70–74 points, 23.5% – 75 points, being the highest index, 23.5% – 60-64 points, and 17.6% – 65–69 points. In the group of people with right hemiparesis, the highest number of patients (36.4%) assessed with the RMI index obtained 70–74 points, 27.3% – 60–64 points, and an equal percentage of patients – 18.27% each – 65–69 points and 75, being the highest number of points. Among patients with left hemiparesis, the highest number of points – 75 was obtained by 33.3% of the patients, the same number of patients obtained 70–74 points, and 16.7% each – 60–64 points and 65–69 points.

Table 5. Patients in the context of the Rivermead performance assessment

	Total		Left hemiparesis		Right hemiparesis	
	N	%	N	%	N	%
60–64 pts	4	23.5%	1	16.7%	3	27.3%
65–69 pts	3	17.6%	1	16.7%	2	18.2%
70–74 pts	6	35.3%	2	33.3%	4	36.4%
75 pts	4	23.5%	2	33.3%	2	18.2%

The assessment of patients on the Scandinavian stroke scale (Table 6) showed that patients with left hemiparesis had an average value of upper limb strength at the level of 5.75 points. (i.e. lifts the limb with the correct strength), lower limb strength 5.25 points (i.e. lifts the straight limb with reduced muscular strength). In the assessment of independence while walking, the mean value in this group was 11.63 points. (i.e. walks 5 m without assistance). The mean value in the assessment of the orientation of the patients with left hemiparesis was 6 points (i.e. full orientation as to time, place and person), and speech - 9.50 points (correct speech). In the group of patients with right hemiparesis, the assessed parameters had lower mean values, i.e. the mean value of the upper limbs strength was 4.40 points (i.e. lifts the limb by bending it at the elbow joint), lower limb strength was 4.50 points (i.e. lifts the limb by flexing it at the knee joint). In the assessment of independence while walking, the mean value in this group was 10.50 points (i.e. walks with auxiliary equipment). The mean value in the assessment of the orientation of the patients with right hemiparesis was assessed at 6 points (i.e. full orientation as to time, place and person), and speech at 8.10 points (choice of words limited, but adequate).

Table 6. Patients in the context of the assessment of fitness on the Scandinavian stroke scale

	Total					Left hemiparesis					Right hemiparesis				
	Mean	SD	Median	Min	Max	Mean	SD	Median	Min	Max	Mean	SD	Median	Min	Max
Upper limb strength	5.0	1.28	5.0	2.0	6.0	5.75	0.46	6.0	5.0	6.0	4.40	1.43	5.0	2.0	6.0
Lower limb strength	4.83	0.99	5.0	2.0	6.0	5.25	0.71	5.0	4.0	6.0	4.50	1.08	5.0	2.0	6.0
Gait	11.0	2.30	12.0	3.0	12.0	11.63	1.06	12.0	9.0	12.0	10.50	2.92	12.0	3.0	12.0
Orientation	6.0	0.0	6.0	6.0	6.0	6.0	0.0	6.0	6.0	6.0	6.0	0.0	6.0	6.0	6.0
Speech	8.72	2.22	10.0	3.0	10.0	9.50	1.41	10.0	6.0	10.0	8.10	2.60	10.0	3.0	10.0

In the results of the tests after rehabilitation, improvement of most of the assessed parameters was observed in all patients, i.e. the length of the COP path with eyes open and closed, load distribution for the left lower limb, deviations in the X axis, eyes open and closed, deviations from the Y axis, eyes open and closed, the area with eyes closed, speed of bending in the X and Y axes with eyes open and closed. However, an increase in the COP surface area with eyes open in the entire study group from 1.86 cm² to 3.29 cm² was observed. The results of the tests taking into account the side of paresis differ both in the assessed parameters of balance and in clinical tests. The results of posturography on the Alpha platform for the study group, including the side of hemiparesis, are presented in Table 7.

Table 7. Summary of the results of the stabilometric assessment of patients in the study group before (test 1) and after (test 2) spa and rehabilitation treatment

Parameters	Test	Total						Left hemiparesis						Right hemiparesis					
		Mn	Mn.D.	SD	Mdn	Min	Max	Mn	Mn.D.	SD	Mdn	Min	Max	Mn	Mn.D.	SD	Mdn	Min	Max
COP path length (eyes open)	1 2	17.94 16.08	1.86	12.15 16.22	14.15 14.20	0.73 1.23	41.17 74.00	12.31 13.08	0.77	6.54 8.17	11.00 11.95	6.11 2.62	22.79 26.59	21.01 17.72	3.29	13.62 19.47	18.79 14.65	0.73 1.23	41.17 74.00
COP path length (eyes closed)	1 2	31.05 27.81	3.24	23.86 17.75	24.58 26.64	3.90 1.11	76.63 64.64	29.45 32.01	2.56	17.91 23.64	29.72 24.90	5.83 8.60	52.94 64.64	31.92 25.52	6.40	27.35 14.43	17.47 27.43	3.90 1.11	76.63 52.45
Deviation from the X axis (eyes open)	1 2	0.12 0.10	0.23	1.47 0.56	0.25 0.13	4.09 1.20	2.87 1.26	0.45 0.05	0.49	1.30 0.72	0.09 0.18	0.53 0.76	2.87 1.26	0.06 0.13	0.08	1.59 0.49	0.39 0.13	4.09 1.20	1.31 0.51
Deviation from the X axis (eyes closed)	1 2	0.14 0.10	0.04	1.58 0.71	0.08 0.07	4.60 1.18	2.92 1.74	0.38 0.10	0.29	1.28 0.91	0.03 0.27	0.65 0.65	2.92 1.74	0.42 0.21	0.21	1.71 0.60	0.18 0.07	4.60 1.18	1.21 0.84
Deviation from the Y axis (eyes open)	1 2	0.81 0.43	0.38	2.10 2.12	0.34 0.75	7.84 3.69	1.57 6.97	0.55 0.97	0.42	1.36 0.44	0.20 0.87	3.21 1.68	0.49 0.48	0.95 0.13	0.81	2.46 2.61	0.58 0.75	7.84 3.69	1.57 6.97
Deviation from the Y axis (eyes closed)	1 2	0.74 0.20	0.54	2.05 2.35	0.16 0.31	7.53 5.14	1.87 7.42	0.79 0.73	0.06	1.21 0.56	0.25 0.60	2.54 1.56	0.38 0.14	0.71 0.09	0.80	2.45 2.90	0.16 0.18	7.53 5.14	1.87 7.42
COP surface area (eyes open)	1 2	1.86 3.29	1.44	2.28 7.01	1.29 1.49	0.01 0.04	9.46 29.89	1.04 1.59	0.55	0.71 1.82	1.02 1.17	0.20 0.11	2.08 5.11	2.31 4.22	1.92	2.72 8.61	1.32 1.49	0.01 0.04	9.46 29.89
COP surface area (eyes closed)	1 2	5.29 3.78	1.51	11.24 3.97	1.80 1.97	0.22 0.05	46.87 13.98	1.92 4.56	2.65	1.61 4.94	1.30 3.24	0.49 0.88	4.28 13.98	7.13 3.36	3.78	13.80 3.53	1.80 1.83	0.22 0.05	46.87 11.58

Mn: mean; Mn.D.: mean value difference; Mdn: median

The mean values of the COP path length in patients with left hemiparesis in the pre-treatment examination were lower than in patients with right hemiparesis. After treatment, the values changed. In the Romberg test with eyes open, the mean length of the COP path before treatment in the group of patients with right hemiparesis was 21.01 cm, and after treatment it decreased to 17.71 cm, the change was not statistically significant ($p = 0.69$). In the Romberg test with eyes closed in this group, the average length of the COP path before treatment was 31.92 cm, and after treatment 25.52 cm, the change was not statistically significant ($p = 0.47$), although the stabilometric balance assessment showed an improvement in the patients' parameters. In patients with left hemiparesis, the mean length of the COP in the Romberg test with eyes open before treatment was 12.31 cm, and after treatment this value increased to 13.08 cm; the change was not statistically significant ($p = 0.82$). In the test with eyes closed for this variable there was an increase in the value from 29.45 cm to 32.01 cm; the change was not statistically significant ($p = 0.63$).

It was studied how the side of paresis in the patients of the study group influences balance and symmetry of the load on the lower limbs. In the case of the parameters concerning the symmetry of loading the lower limbs, no statistically significant differences were found between the mean results of the tests in patients with left hemiparesis ($p = 0.98$) and right hemiparesis ($p = 0.39$), both in the tests before and after treatment, although there were some regularities. In patients with right hemiparesis after treatment, the mean value of load distribution for the right (affected by paresis) lower limb was 50% and for the left (unaffected) lower limb it was also 50%, which may indicate an improvement in balance parameters. In patients with left hemiparesis before treatment, a greater load on the right lower limb (unaffected) was observed – mean value 50.36% – than on the left one: 49.64%. Lower limb load disproportions after treatment remained; the mean percentage load value of the right (unaffected) lower limb was 50.39%, and of the left (affected by paresis) lower limb – 49.61%.

In the results of patients with right and left hemiparesis, statistical differences were noticed in relation to the bending of the COP point in the lateral direction with eyes open and in the anteroposterior direction with eyes open. It was observed that under direct vision the patients with right hemiparesis had greater problems with maintaining balance in the frontal plane than those with left hemiparesis.

In the Romberg test with eyes open, the deviation from the X axis (in the frontal plane) for the entire group was 0.12 cm on average, and 0.10 cm after treatment, i.e. less by 0.02 cm. In patients with left hemiparesis before treatment, it was 0.45 cm, and after treatment, the deviation in the frontal plane was reduced to 0.05 cm. The observed improvement was not statistically significant ($p = 0.26$). Similarly, the lack of statistical significance of the results before and after treatment was observed in patients with right hemiparesis. The value of the deviation in the frontal plane from the X axis was 0.06 cm before treatment and 0.13 cm after treatment.

In the Romberg test with eyes closed in the study group, a reduction in the deviation of the COP in the frontal plane (deviation from the X axis) was observed for the entire group, on average from 0.14 to 0.10 cm after treatment, i.e. by 0.4 cm. In patients with left hemiparesis before treatment, the deviation value was 0.38 cm, and after treatment, the deviation in the frontal plane was reduced to 0.10 cm. The observed improvement was not statistically significant ($p = 0.24$). Similarly, the lack of statistical significance of the results, despite their improvement after treatment, was observed in patients with right hemiparesis ($p = 0.67$). The value of the deviation in the frontal plane from the X axis was 0.42 cm before treatment and 0.21 cm after treatment (Table 7).

In the assessment of deviations from the Y axis (in the sagittal plane) in the Romberg test with eyes open, a reduction in bending was observed in patients with right hemiparesis from 0.95 cm before treatment to 0.13 cm after treatment. The change towards improved stability was not statistically significant ($p = 0.50$). On the other hand, in patients with left hemiparesis the parameter increased from 0.55 cm to 0.97 cm. The observed change was not statistically significant ($p = 0.52$) – Table 7.

In the assessment of deviations from the Y axis (in the sagittal plane) in the Romberg test with eyes closed, a reduction in bending was observed in patients with left hemiparesis from 0.79 cm before treatment to 0.73 cm after treatment, and in patients with right hemiparesis, respectively, from 0.71 cm to 0.09 cm. The observed changes indicate an improvement in stability of the patients, although they were not statistically significant ($p = 0.90$; $p = 0.53$).

Although the patients underwent rehabilitation aimed at restoring lost functions, improving balance during standing and walking, the values describing the COP surface area in the test with eyes open in the study group increased after treatment, respectively in patients with left hemiparesis from 1.04 cm^2 to 1.59 cm^2, the change was not statistically significant ($p = 0.42$), and in patients with right hemiparesis from 2.31 cm^2 before treatment to 4.22 cm^2 after treatment, the change was not statistically significant ($p = 0.52$).

The value describing the COP surface area in the test with eyes closed in patients with right hemiparesis decreased from 7.13 cm^2 before treatment to 3.36 cm^2 after treatment, indicating an improvement in balance control, although the observed change was not statistically significant ($p = 0.41$). In the patients with left hemiparesis, an increase in the COP surface area in the test with eyes closed was observed from 1.92 cm^2 before treatment to 4.56 cm^2 after treatment, the observed change was not statistically significant ($p = 0.41$) – Table 7.

A change in the speed of bending was observed in relation to both the X and Y axes. In patients with right hemiparesis, the speed of the COP bending, both in the test with eyes closed and open in the frontal (X) and sagittal (Y) planes, decreased after spa treatment. The value of the speed of bending in the test with eyes open in the X axis before treatment was 0.35 cm/s, and 0.29 cm/s after treatment, and in the Y axis, respective-

ly, 0.37 cm/s before treatment and 0.29 cm/s after treatment. In the test with eyes closed, the speed of the COP bending in the X axis before treatment was 0.48 cm/s, and after treatment 0.39 cm/s, while in the Y axis (anterior-posterior plane) it was 0.59 cm/s before treatment and 0.48 cm/s after treatment. The observed changes were not statistically significant, but indicate an improvement in the control of the nervous system. In patients with left hemiparesis, the speed of the COP bending parameter increased slightly after treatment, but the obtained values were lower than those obtained before and after treatment in patients with right hemiparesis in the test with eyes open in the X axis, i.e. 0.20 cm/s before and 0.22 cm/s after treatment, and in the Y axis, i.e. 0.22 cm/s before treatment and 0.24 cm/s after treatment. On the other hand, the speed of COP movement in the X axis with eyes closed was higher in this group, i.e. 0.44 cm/s before treatment and 0.49 cm/s after treatment, and in the Y axis 0.56 cm/s before and 0.60 cm/s after treatment. The obtained results were not statistically significant. The obtained results of the statokinesigram and stabilogram indicate a dynamic change of parameters after treatment (Table 7).

In addition to the objective method of assessing balance using posturography, clinical quantitative tests were used (Table 8). Balance assessment carried out with the use of TUG allows to conclude on very clear, statistically significant effects of rehabilitation. The improvement in balance was expressed by shortening the task completion time for the entire group by an average of 1.32 s (9.4%). Patients with right hemiparesis performed the activities included in the TUG test faster by 1.37 s (9.0%), i.e. before treatment they had an average time of 15.18 s, and after treatment 13.81 s. The value of the changes obtained was statistically significant ($p \leq 0.01$). In patients with left hemiparesis, the mean time to perform the TUG test before treatment was 12.22 s, and after treatment 10.97 s, i.e. faster by 1.25 s (10.2%). The observed improvement was statistically significant ($p \leq 0.03$). Differences in the time of all the patients covering the distance of 10 meters with their own (comfortable) speed (10MWT) and maximum speed (10mSz) were observed. All patients covered this distance at their own pace before treatment on average in 13.86 s, and after treatment in 13.10 s, i.e. faster by 0.76 s (5.5%). The patients with left hemiparesis covered this distance with their own (comfortable) speed before treatment on average in 13.37 s. After treatment the time was shortened by 1.49 s (11.2%) and amounted to 11.88 s; the change was not statistically significant ($p = 5.03^{-3}$). Under the same test conditions, the patients with right hemiparesis achieved an average time of 14.13 s before treatment and 13.77 s after treatment, i.e. faster by 0.36 s (2.6%); the change was not statistically significant ($p = 0.28$). At the maximum speed before treatment, the average time of all patients was 11.75 s, and 11.15 s after treatment, i.e. faster by 0.60 s (5.1%). The patients with left hemiparesis covered the distance of 10 m in an average time of 10.92 s, and after treatment the time was shortened by 0.76 s (7%) and amounted to 10.16 s ($p = 8.48^{-3}$); while the patients with right hemiparesis before treatment covered the distance on average in 12.20 s and after treatment in 11.69 s, i.e. faster by 0.51 s (4.2%). The results obtained in the 10MWT

and 10mSz tests are not statistically significant, however, they indicate the direction of functional improvement in gait. Clear differences were also observed in the patients of the study group in the distance of walking. In the 2-minute walk test, the change affected the entire study group, i.e. before treatment, the average distance was 112.35 m, and after treatment it increased by 8.97 m (i.e. by 8%) and amounted to 121.32 m.

Table 8. Patients in the context of the assessment according to clinical quantitative tests before and after spa and rehabilitation treatment

	Total								Left hemiparesis			
	before	after	t	p	before	after	t	p	before	after	t	p
	Średnia/Mean ± SD				Średnia/Mean ± SD				Średnia/Mean ± SD			
10 meter quick walk test	11.75 ± 5.72	11.15 ± 5.68	3.47	3.18^{-3}	10.92 ± 2.65	10.16 ± 2.39	4.20	8.48^{-3}	12.20 ± 6.94	11.69 ± 6.92	2.04	0.07
10 meter slow walk test	13.86 ± 6.69	13.10 ± 6.69	2.88	0.01	13.37 ± 1.96	11.88 ± 2.48	4.77	5.03^{-3}	14.13 ± 8.33	13.77 ± 8.20	1.14	0.28
2-minute walk test	112.35 ± 33.94	121.32 ± 32.69	6.96	< 0.001	104.00 ± 25.71	117.33 ± 21.13	−5.68	2.36^{-3}	116.91 ± 38.05	123.50 ± 38.36	−6.60	< 0.001
Timed up and Go	14.13 ± 7.96	12.81 ± 7.39	4.18	< 0.001	12.22 ± 3.54	10.97 ± 2.87	3.01	0.03	15.18 ± 9.57	13.81 ± 8.96	3.04	0.01

In patients with right hemiparesis, the distance covered increased from an average of 116.91 m before treatment to 123.50 m after treatment, i.e. by 6.59 m (5.6%). The change in distance was statistically significant ($p < 0.001$). In patients with left hemiparesis, the assessed parameter increased from 104.00 m before to 117.33 m, i.e. by 13.33 m (12.8%) after treatment. The observed improvement in walking distance was not statistically significant, but it was functionally significant. The functional assessment of balance and locomotion shows that the applied spa and rehabilitation treatment had an impact on the improvement of time and space parameters in the patients in the study group.

Discussion

The patients in the study group were differentiated due to the side of the paresis and the degree of independence assessed by clinical tests. Patients with left hemiparesis achieved a higher degree of independence in performing basic activities of daily living, assessed on the following scales: Barthel, Katz, and Rivermead. The assessment of the degree of independence during walking using the FAC test also showed that the patients with left hemiparesis were independent and completely independent in locomotion compared to the group of patients with right hemiparesis. This was also confirmed by the results of the assessment of the neurological deficit in the SSS scale. Patients with left hemiparesis were independent when walking. Cognitive functions, speech, and orientation were normal. The muscular strength

of the lower and upper limbs was close to the normal value compared to the patients with right hemiparesis. The study group involved patients long after a stroke, on average about 8.73 years in the case of patients with right hemiparesis and 5.67 years in the case of patients with left hemiparesis. Such characteristics may indicate the occurrence of permanent compensatory changes in motor stereotypes over the years, especially in strategic functions such as gait, balance and stability, and could have influenced the treatment outcomes. There were also differences in the patients' age. Patients with right hemiparesis were on average 7.9 years younger than those with left hemiparesis. The importance of the age of the patients and the time from a stroke in the return of lost motor functions is emphasized by many authors. It was pointed out by Fedak et al. [12] in her studies, confirming the influence of age and time from a stroke on the results obtained in posturography. However, this is not confirmed by the study by Drużbicki et al. [6], which showed that age and time from a stroke do not affect the level of the tested measures of fitness, and by Woldańska-Okońska [13], indicating that neither age nor gender should be treated as a prognostic criterion for the assessment of rehabilitation in patients after a stroke. Many authors have also addressed the problem of the influence of the side of paresis on the physiotherapeutic effect [2, 14, 15, 16].

In our study, a greater improvement in posturography on the stabilometric platform can be noticed in the younger group of patients with right hemiparesis. In the objective evaluation after treatment, in the group of patients with right hemiparesis, there was an improvement in the parameters influencing the efficiency and quality of gait, i.e. shortening the length of the COP path with eyes open, with eyes closed, and equalization of load distribution on the lower limbs, which is an important factor in the improvement of balance. In patients with left hemiparesis, no shortening of the COP path and no equalization of the load asymmetry of the lower limbs were observed. Pop et al. emphasizes the influence of the side of paresis on the symmetry of the load on the lower limbs in a study conducted in a group of 51 patients after a stroke. They found that worse results of the symmetry of load on the lower limbs occur in patients with damage to the right hemisphere of the brain (left hemiparesis), which confirms the relationship of the right hemisphere with the orientation of the body in space and the arrangement of receptive fields. They also show that people with right hemiparesis overloaded the left lower limb by 1%, and people with left hemiparesis overloaded the right lower limb by 9% [17]. Other authors also pointed to the improvement of balance in patients with left hemispheric injury (with right hemiparesis) in posturography [18, 19].

This fact is also confirmed by the results of this study. In patients with right hemiparesis, there was a reduction in the deviation from the X axis with eyes closed, a reduction in the deviation from the Y axis with eyes open and closed, a reduction in the COP surface area with eyes closed, a reduction in the speed of bending in the X axis with eyes open

and closed, and a reduction in the speed of bending in the Y axis (in the sagittal plane) with eyes open and closed. The observed changes indicate an improvement in the patients' balance and postural control.

At the same time, it should be noted that in the objective assessment of the variables determining the quality of gait, especially the length of the COP path with eyes open and closed, the distribution of loads on the lower limbs, deviations from the X and Y axes (in the frontal and sagittal plane) with eyes open and closed, the COP surface area with eyes open and closed, as well as the speed of bending in both X and Y axes in patients with left hemiparesis, no improvement was observed in these parameters.

The objective image of the changes in parameters after treatment shows that the group of patients with right hemiparesis achieved greater improvement in the objective assessment of neuromuscular balance and coordination in relation to patients with left hemiparesis. However, due to the small group of study participants, in this case we can talk more about the direction of observation than treat the obtained results as principles.

When analysing the results of the COP path length with eyes open, the COP surface area with eyes open, deviations from the X and Y axes with eyes open and closed, as well as the speed of bending in both X and Y axes with eyes open, the lower value of these parameters is noticeable, both in pre-treatment and post-treatment tests in patients with left hemiparesis compared with values obtained by patients with right hemiparesis, which may affect postural control, neuromuscular coordination in gait and the results obtained by these patients in functional tests - 2MWT, 10MSzT, 10MWT, TUG. These observations are consistent with the studies conducted by Pop et al., which show that in the studies conducted in a group of 51 patients after a stroke, no statistically significant influence of the side of paresis on the balance was found, however, the results were worse in patients with right hemiparesis compared to those with left hemiparesis in the length of the path covered by the projection of the centre of pressure of the feet onto the platform (COP) [17].

In our study, the baseline values in the study of the COP path length with eyes open in patients with right hemiparesis before and after treatment, despite improvement, were also higher than in patients with left hemiparesis.

The program of comprehensive spa and rehabilitation treatment, including balance control exercises on a stabilometric platform, improved the patients' walking speed. The patients subjected to the functional assessment of gait, especially the time-space parameters (speed, distance), regardless of the side affected by paresis, showed an improvement in the efficiency of these parameters after treatment. Bugajski and Czernicki also indicate the tendency to reduce the time needed to cover 10 meters in the walk speed test in patients long after a stroke [5, 20, 21, 22].

In the study, the 10-metre walk test showed an improvement in the natural pace (10MWT) and fast pace (10MSZT) for

the entire group. At the same time, there is a greater improvement in time parameters in the group of patients with left hemiparesis in walking with the natural and fast pace. Patients with left hemiparesis achieved slightly better results compared to those with right hemiparesis, i.e. in the 10MWT test they covered the distance in a shorter time compared to patients with right hemiparesis. Similarly, in 10MSzT, the walking time of the distance of 10 metres by patients with left hemiparesis at the maximum pace was shorter than by patients with right hemiparesis. In the group of patients with right hemiparesis, the improvement was smaller in walking at the natural pace and at the fast pace.

Similar observations concern the assessment of gait of the patients in the TUG test, where patients with left hemiparesis completed the task in an average time shorter by 2.84 s than patients with right hemiparesis. Similarly, the improvement of balance expressed by shortening the task time by 4.4 s in the "Get Up & Go" test in 30 patients long after a stroke (over 6 months) was demonstrated by Drużbicki et al. [9].

Literature shows the time criterion in the TUG test as differentiating patients experiencing falls or not experiencing falls, the so-called cut-off point according to Skumwaylook et al. - 13.5 s limit in the TUG test (ICC intraclass correlation coefficients – intra-rate – 0.99) [10].

It should be noted that the improvement of the time parameters in the TUG test in patients with left hemiparesis to the value of 10.97 s and with right hemiparesis to 13.81 s after treatment places this group in the lower limit in terms of falls according to the ICC index.

In terms of gait efficiency in the 2-minute walk test, patients with left hemiparesis walked a longer distance than those with right hemiparesis. Drużbicki et al., in a study of gait in 48 patients with hemiparesis after a stroke, found a clear relationship between the speed of walking and the distance of walking in the 2-minute walk test – patients who covered the distance of 10 m faster, by about 0.2 m/s, walked a distance greater by about 20 m in the 2-minute walk test [6].

The results of the functional assessment obtained in the 10MWT, 10MSzT, TUG and 2MWT tests in patients with left and right hemiparesis indicate an improvement in gait parameters and gait stability.

Comprehensive spa and rehabilitation treatment has a multidimensional impact on patients after a stroke and creates optimal conditions for working on the control function of the neuromuscular system lost as a result of a stroke. Specific balneological methods, physical treatments, massage, individual neurophysiological kinesiotherapy methods supplemented with training on the basis of modern devices, such as the Alpha stabilometric platform, enable patients to regain their motor skills even long after a stroke. Exercises on the stabilometric platform give measurable therapeutic effects in improving the balance parameters. The influence of exercises on a stabilometric platform with biofeedback in patients after a stroke on a statistically significant improvement in the symmetry of the load on the lower limbs is also emphasized in the research conducted by Kołcz-Trzęsicka et al. [14, 16, 23], also pointing to their usefulness in comprehensive rehabilitation after a stroke.

The platform is an important therapeutic and diagnostic tool, it enables monitoring of the obtained improvement in an objective dimension and is a sign of modernity in spa treatment of patients after a stroke.

Conclusions

1. The program of comprehensive spa and rehabilitation treatment, enriched with training with the use of a stabilometric platform, had a positive effect on the improvement of balance parameters and gait function in patients long after a stroke.
2. Objective improvement of the balance parameters in the stabilometric evaluation after 3 weeks of spa and rehabilitation treatment was noticed in the younger group of patients with right hemiparesis long after a stroke.
3. Patients with left hemiparesis performed their tasks quicker in the 10MWT, 10MWT, and TUG clinical tests and covered a longer distance in the 2MWT test.
4. Therapy on a stabilometric platform with the use of biofeedback should constitute a standard element of therapy in patients after a stroke.

Adres do korespondencji / Corresponding author

Agnieszka Nitera-Kowalik

e-mail: agnieszka.kowalik@szpitalwojskowy.pl

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