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The influence of deep sensory foot stimulation on balance and gait function in patients with hemiparesis

Wpływ głębokiej stymulacji czuciowej stopy na równowagę i funkcję chodu chorych z niedowładem połowiczym

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Key words
stroke, hemiparesis, Bobath concept, balance, gait, sensory stimulation

Summary
Background: Current research emphasizes the importance of sensory afference for movement control. Multisensory information may be processed in the brain even when its damage is located in multimodal association areas and specific sensory cortex.
Aim: The aim of the study was to assess the influence of sensory stimulation of the hemiparetic foot on balance and gait improvement in stroke patients with respect to the their age, time from onset and location of stroke.
Material and methods: The study was carried out from March to July 2016 and involved 40 consecutive inpatients (age 39-86 years; mean=68,3; *SD*=10.2) staying at the "Pasternik" rehabilitation centre in Modlniczka for 6 weeks. On the day of the physician's examination, medical history was recorded and patients were interviewed about their health condition. After that, three functional tests were carried out: the Two-scale test, the Tinetti test and the Timed Up and Go test (TUG). The measurements were taken: before sensory stimulation, after the first treatment, after 4 weeks of treatment and at 2 weeks of follow-up. Every day, treatment consisted of individual sensory stimulation of the hemiparetic foot performed by a physiotherapist according to the specific principles of the Bobath concept. Additionally, aimed at foot sensory stimulation, patients performed their own supervised exercises using designated equipment at a gym.
Results: 4 weeks of treatment aimed at the sensory stimulation of the hemiparetic foot influenced balance and gait improvement in stroke survivors. Significant improvement in weight distribution on the Two-scale test was detected immediately after the first stimulation. The results of both gait tests measured after 4 weeks of physiotherapy allowed to classify subjects into the group of average fall risks in comparison to the initial high-risk group. The study indicated more efficacy of sensory stimulation in younger patients with left side paresis and a shorter period after stroke onset.
Conclusion: Foot sensory stimulation is a non-invasive, efficient therapeutic tool for regaining balance and gait improvement in hemiparetic subjects after stroke.

Słowa klucze
udar, hemiplegia, koncepcja Bobath równowaga, chód, stymulacja czuciowa

Streszczenie
Wprowadzenie: Aktualnie prowadzone badania naukowe podkreślają znaczenie informacji sensorycznej dla kontroli ruchowej. Informacja multisensoryczna może być przetwarzana przez mózg nawet wtedy, gdy jego uszkodzenie obejmuje multimodalne obszary kory kojarzeniowej oraz specyficzne obszary kory czuciowej.
Cel: Celem badania była ocena wpływu stymulacji czuciowej stopy na równowagę i funkcję chodu osób z niedowładem połowiczym z uwzględnieniem wieku badanych, okresu, który upłynął od udaru oraz jego lokalizacji.

The individual division of this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication sear

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Materiał i metody: Badaniami prowadzonymi od marca do lipca 2016 roku objęto grupę czterdziestu kolejnych chorych (wiek 39-86 lat; średnia=68,3; *SD*= 10,2) leczonych w ośrodku rehabilitacyjnym NZOZ Pasternik w Modlniczce, przebywających na 6 tygodniowym turnusie rehabilitacyjnym. W dniu konsultacji lekarskiej przeprowadzono wywiad i ankietę na temat stanu zdrowia, a następnie przeprowadzono badanie przedmiotowe złożone z 3 testów funkcjonalnych: testu dwóch wag, testu Tinetti, oraz testu „Wstań i idź" (TUG). Pomiary wykonano czterokrotnie: przed rozpoczęciem usprawniania, pierwszego dnia po fizjoterapii, po 4 tygodniowym okresie usprawniania oraz po 2 tygodniowej przerwie. Codzienna rehabilitacja obejmowała indywidualną stymulację sensoryczną stopy wykonaną przez fizjoterapeutę zgodnie z założeniami koncepcji Bobath. Dodatkowo pacjenci mieli dostęp do sali gimnastycznej, gdzie wykonywali samodzielnie zadane ćwiczenia ukierunkowane na sensorykę stopy przy wykorzystaniu odpowiednich przyrządów terapeutycznych.

Wyniki: Czterotygodniowa fizjoterapia dedykowana stymulacji sensorycznej niedowładnej stopy wpłynęła na poprawę równowagi i funkcji chodu u chorych z niedowładem połowiczym. Znamienną poprawę w symetrii rozkładu ciężaru ciała na dwóch wagach zanotowano już po pierwszej stymulacji. Wyniki obu testów chodu po zakończeniu fizjoterapii pozwoliły na zakwalifikowanie chorych do grupy osób o średnim ryzyku upadku z wyjściowo wysokiego ryzyka. Badanie wykazało również korzystniejszy wpływ terapii na usprawnienie osób młodszych, z porażeniem lewostronnym oraz krótszym okresem od incydentu udarowego.

Wnioski: Stymulacja sensoryczna stopy jest nieinwazyjnym i skutecznym narzędziem terapeutycznym w przywracaniu równowagi i poprawie chodu u osób z niedowładem połowiczym po przebytym udarze mózgu.

INTRODUCTION

Planning or executing any motion requires the central nervous system to selectively acquire and process sensory information about the current and predicted position of the body. This is possible due to constant integration of various sensory stimuli received during the currently performed or planned physical activity[1]. More than half of the human cerebral cortex is covered by associative areas that process events occurring in the human sensorimotor system. These areas are responsible for planning, thinking, memory processes, emotions and motor performance[2]. They execute continuous processing of sensory information that modulates motor activity at all levels of the central nervous system. This integration is called multisensory, and as suggested by research, it is thanks to this integration that the brain builds a coherent representation of its own body and environmental schema, also allowing detection and localization of external phenomena[3]. Combining information coming from different sensory channels turns out to be particularly beneficial in a situation when a single-source signal can only slightly trigger a motor response, or when the sensory system as a whole is weakened[3]. Individuals with neurological dysfunctions who have lost one or more senses can, therefore, have clearly marked motor dysfunctions, even if they have maintained normal muscular strength. In light of so much important information for motor performance, it is indicated that the effectiveness of rehabilitation after a stroke can be determined by the degree of sensory disorder, or that it is a prognostic factor of neurorehabilitation results[1]. The direct consequence of such beliefs is the introduction of various sensory stimulation techniques. Their implementation is based on the use of brain tissue plasticity and the assumption that this plasticity can be stimulated accordingly. Generally speaking, the brain adapts to pathological changes by using alternative connections to bypass the damaged area[4,5]. In addition, researchers confirm that multi-sensor information may still be processed to a certain extent, even when the damage includes multimodal areas of the cortex and specific areas of the sensory cortex[6]. This is due to the fact that many brain structures, including specific sensory centres, will still be able to support the processing of such information. Multi-sensory stimulation can trigger the reserve of neural activity of the damaged area when it comes from different senses simultaneously[6]. This is manifested, for example, in its improved detection, as the neuronal activity is able to exceed the required threshold of excitability. The sensory stimulation techniques regard: proprioceptive stimulation, the vestibular and visual systems[7,8]. As indicated by the study results, these interventions affect the reduction of motor disorders after stroke, including balance disturbances and signs of spatial neglect[9].

STUDY AIM

The aim of the study was to examine whether intense sensory stimulation of the foot can influence the improvement of balance and gait functions in patients after stroke.

The following research questions were posed:

1. Does deep sensory stimulation affect the improvement of motor function in patients?
2. Does the effect of therapy persist after its completion?
3. Does the length of the period from onset have an effect on the patient's balance and gait function?
4. Does the patient's age influence the outcome of stimulation?
5. Does the location of damage in the left or right hemisphere of the brain contribute to the modification of therapeutic results?

MATERIAL AND METHODS

Course of the study

The research conducted from March to July 2016 included a group of 40 patients from the non-public "Pasternik" rehabilitation centre in Modlniczka, staying at the rehabilitation facility for 6 weeks. All subjects were qualified for rehabilitation by a physician, were informed about the purpose and course of the study and expressed their voluntary consent for participation. On the day of the medical consultation, an interview and questionnaire were conducted regarding health, followed by a physical examination. Each of the patients underwent 3 functional tests: the Two-scale test, the Tinetti test and the Timed Up and Go test (TUG) according to the following scheme:

- before physical therapy (Measurement No. 1)
- immediately after the first physical therapy session (Measurement No. 2),
- after 4 weeks of physical therapy (Measurement No. 3),
- after a 2-week break following the completion of physical therapy (Measurement No. 4).

Daily rehabilitation included 30 min. of individual therapy with a physical therapist. In addition, patients had access to the gym, where independently performed supervised exercises using equipment.

Research tools

The Two-scale test

The Two-scale test – used to study the symmetry of body mass distribution between the right and left lower limbs (Photo 1). The patient stands on equal-sized scales so that the right and left lower limbs are in the same position, each on their own scale. The permitted difference is 1-1.15 kg. This test was previously used in stroke patients[10].

The Timed Up and Go test

The Timed Up and Go test (TUG) is used in the evaluation of functional efficiency and the risk of falls[11,12].

On "start", the subject must:

1. Stand up from a chair;
2. Cover a 3 m distance;
3. Cross the finish line of the appointed distance;
4. Perform a 180 degree turn;
5. Go back to the chair and assume a seated position.

Interpretation of results:

- less than 10 seconds - standard, functional efficiency (low risk of falls),
- 10-19 seconds – the subject is independent in most everyday activities and may go outside alone; does not need walking aids (average risk of falls),
- exactly 19 seconds or more - functional efficiency limited to a large extent, the subject is not able to go outside independently and needs supportive equipment for walking (high risk of falls)[11,12].

The Tinetti test

The Tinetti test is a complex examination used to assess stability, balance and gait function in older people as well as those with neurological disorders. It is similar to the Timed Up and Go test, however, it is divided into 17 different tasks rated on a 0, 1 or 0, 1, 2 scale. The first part of the test is dedicated to assessing balance in static positions such as sitting and standing, as well as during changes in position, including the transition from sitting to standing or rotation while maintaining in one spot. For the 9 tasks of this part of the test, a maximum of 16 points can be achieved. The second part of the test, in which the next 7 tasks are assessed, concerns gait. The test examines, among others, the length and height of a step, its symmetry, gait path as well as posture of the examined subject. The correct performance of this part of the test allows to obtain another 12 points[13].

Interpretation of the results[13]:

- below 19/28 points: a person with a high risk of falls,
- 19 and 24/28 points: a person prone to falls,
- above 24/28 points: a person with low or no risk of falls.

Photo 1
The Two-scale test

Utilized therapeutic methods

In order to perform sensory stimulation of the foot, therapeutic interactions were applied in accordance with the assumptions of the Bobath concept. This concept is currently defined as an individualized and comprehensive approach to the examination and therapy of people with functional, motor and tension-related disorders caused by damage to the central nervous system[14,15]. Many years of expert work on this concept have led to the formulation of the model of Bobath clinical practice (MBCP), which enables therapists to build an individualized intervention plan addressing all components of motor performance[16]. One of the fundamental principles of the concept is the role of afferent stimulation for optimizing body scheme, performing a motor task and the motor learning process[17]. In the Bobath approach, sensorimotor improvement of significant motor tasks for the patient, with emphasis on the primary disorder of body structures and functions, is aimed at promoting plasticity changes in the brain[18]. Based on key components of the clinical practice model, i.e. the functional analysis of movement, skilful facilitation and clinical reasoning in individual patients, the selected facilitation techniques were used:

Photo 2

Stimulation of the longitudinal arch and lateral side of the foot along with mobilization of the Achilles tendon along the course of the fibres

Photo 4

Stimulation of the transverse arch of the foot and mobilization of the metatarsus

Photo 3

Sensory stimulation of the Achilles tendon by mobilising the tendon in the plantar direction from the medial and lateral sides

- Foot mobilization emphasizing pronation, with plantar and dorsal flexion of the foot;
- Stimulation of the longitudinal arch and the external part of the foot, covering the Achilles tendon along the course of the fibres (Photo 2);
- Sensory stimulation of the Achilles tendon rubbing its insertion in the plantar direction from the medial and lateral sides (Photo 3);
- Mobilization of the metatarsus, covering the transverse arch of the foot (Photo 4);
- Sensory stimulation of the heel (Photo 5);
- Sensory stimulation of the foot, with emphasis on pronation (Photo 6);
- Mobilization of the triceps surae muscle (Photo 7);
- Additionally, each patient had the task of independently performing stimulation of the bare foot. These tasks were adapted to the patients' capabilities and were performed both with open and covered eyes. An example of the task:
  – stimulation using sensory cushions (Photo 8).

Photo 5

Sensory stimulation of the heel

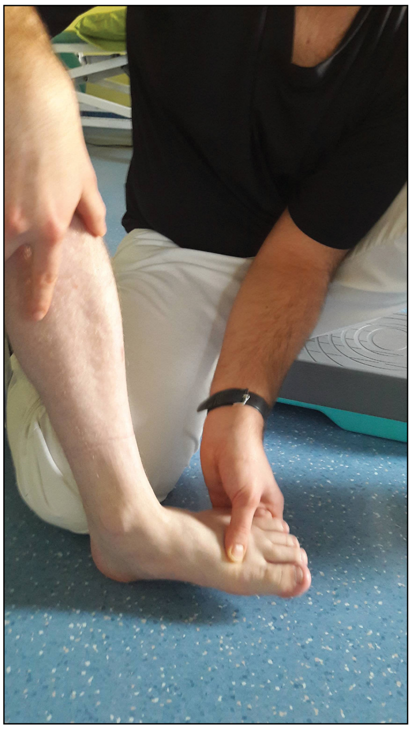

Photo 6
Sensory stimulation of the foot in pronation

Photo 7
Mobilization of the triceps surae

Photo 8
Stimulation using sensory cushions

Tools and methods of statistical analysis

During analysis, an Excel spreadsheet and Statistica – version 10.0 were used. Significance tests – using the STATISTICA programme, a series of tests was carried out for the significance of differences regarding dependent samples. These types of tests are performed when analysing the same group repeatedly. Each variable marked with the number 1 means that the test was carried out before treatment. In turn, each variable marked with the number 4 means that analysis was carried out at the completion of therapeutic tests. Significance tests were carried out not only for the whole group of patients, but also, the division into individual subgroups was taken into consideration. It is worth noting that between measurements No. 1 and 4, No. 2 and 3 also took place (respectively: after the first therapy session, after a month of therapy). Due to the fact that not only the impact of the same treatments on the improvement of patients' health is examined, but also whether their effects are long-lasting, it was decided to carry out significance tests for the first measurement and the last one. During the analysis, the significance level was set at $\alpha = 0.05$.

Correlation of results – in the calculation of the results shown in the Matrix correlation (Table 2), the Excel spreadsheet was used as well as the built-in "=PEARSON" function, which calculates the correlation level of the two selected variables.

The Two-scale test variables 1, 2, 3, 4, were calculated as the absolute value of the difference between weights A and B for each patient individually.

RESULTS

Detailed characteristics of the study participants

30 patients with right- and left-sided paresis were included in the study. The age of the patients oscillated between 39 and 86 years (mean: 68.3 years, SD = 10.2). Persons suffering from left-sided paresis were on average 4 years younger (mean: 66.0 years, SD = 12.6) than those suffering from right-sided paresis (mean: 70.7 years, SD = 6.5). Among patients with right-sided paresis, there was not a single person under the age of 50.

Over half of the subjects (n = 23) suffered a stroke less than two years prior to the study. The average age in this group was 70.7 years (SD = 8.1), which is an average of 6 years more than among those who suffered from stroke more than two years earlier (mean = 65.0 years, SD = 12.0).

Functional test results

Two-scale test results

Before beginning physical therapy (Measurement No. 1), asymmetry in loading the right and left lower limbs was found, 4.7 kg (*SD* = 2.9) on average. The subjects did not properly weigh-down the directly affected lower limb. After the test (Measurement No. 4), the obtained results indicated a significant decrease in asymmetry – mean = 2.7 kg (*SD* = 1.6) ($p<0.0001$).

Table 1

Significance tests for the Two-scale test (Measurement No. 1 vs. Measurement No. 4)

Significance tests	Sub-group	Measurement	Average	*SD*	Number of considered variables	Difference	*SD*	*t*	*df*	*p*
Two-scale test	Total	Measurement No. 1	4.7	2.9						
		Measurement No. 4	2.7	1.6	40	2.1	2.4	5.4	39	**<0.0001**
Two-scale test divided according to age	≤ 68 years	Measurement No. 1	4.8	2.2						
		Measurement No. 4	2.6	1.5	20	2.2	2.1	4.6	19	**<0.001**
	> 68 years	Measurement No. 1	4.7	3.5						
		Measurement No. 4	2.7	1.8	20	2.0	2.8	3.2	19	**<0.05**
Two-scale test divided according to side of paresis	Right-sided paresis (stroke in left hemisphere)	Measurement No. 1	4.3	2.5						
		Measurement No. 4	2.5	1.7	20	1.8	2.2	3.7	19	**<0.05**
	Left-sided paresis (stroke in right hemisphere)	Measurement No. 1	5.2	3.3						
		Measurement No. 4	2.9	1.5	20	2.3	2.7	3.8	19	**<0.05**
Two-scale test divided according to time from stroke	More than two years	Measurement No. 1	4.4	2.4						
		Measurement No. 4	2.7	1.8	17	1.7	2.4	2.9	16	**<0.05**
	Less than two years	Measurement No. 1	4.9	3.2						
		Measurement No. 4	2.6	1.5	23	2.3	2.4	4.6	22	**<0.001**

Measurement No. 1 – before beginning physical therapy; Measurement No. 4 – after a 2-week break following the completion of the performed physical therapy

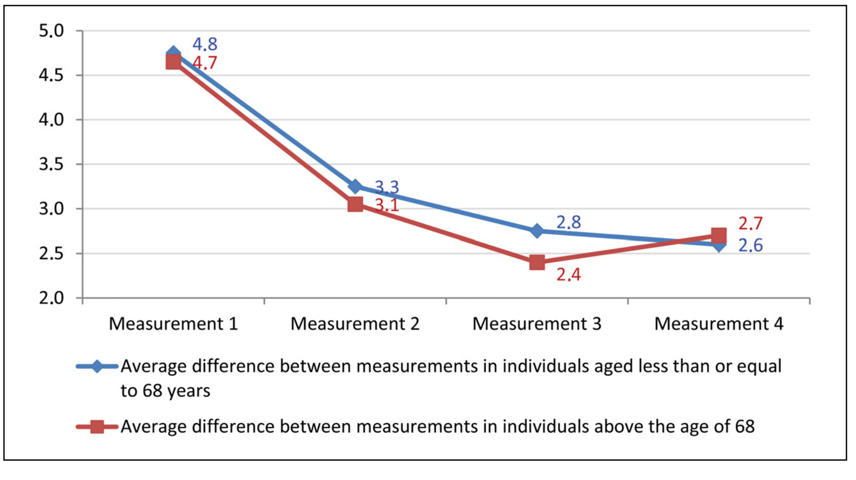

Figure 1

Average difference in weight A and B in particular measurements for sub-groups differing in age (n=40)

These results were also observed in subgroups that differed in age, stroke location and time that elapsed since the stroke incident (Table 1).

It should be noted that the results of measurements made after the first sensory stimulation session (Measurement No. 2) have already indicated a more symmetrical distribution of body mass between the lower limbs (mean = 3.2 kg, *SD* = 2.0) ($p<0.001$). A further 4 weeks of physical therapy resulted in evenly balanced weight distribution (mean 2.6 kg, *SD* = 1.6) (Measurement No. 3), persisting for another 2 weeks despite lack of sensory stimulation during this period (mean = 2.7 kg; *SD* = 1.6) (Measurement No. 4).

The same analyses carried out in subgroups of subjects differing in age indicated higher effectiveness of sensory therapy in patients over the age of 68, however, discontinuation of therapy caused slight deterioration in this group. In younger patients (under the age of 68), improvement was maintained even after cessation of stimulation (Figure 1).

Similar results were obtained by analysing the subgroups of patients

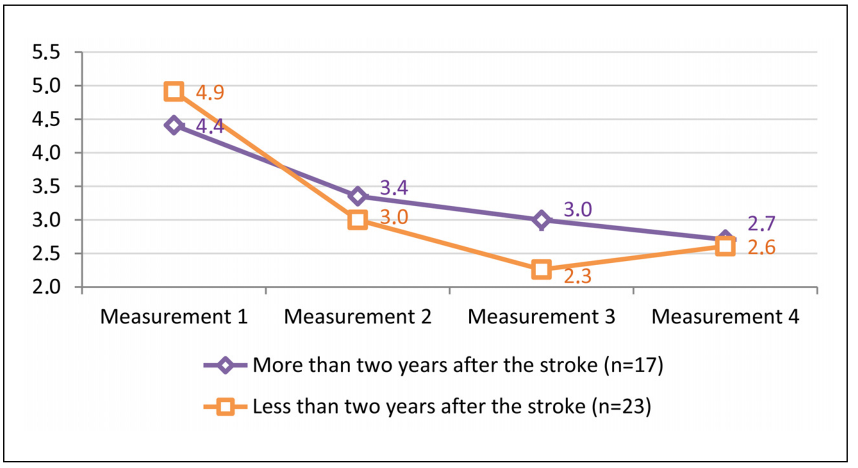

Figure 2

Average differences between weight A and B in particular measurements among sub-groups differing in time from stroke (n=40)

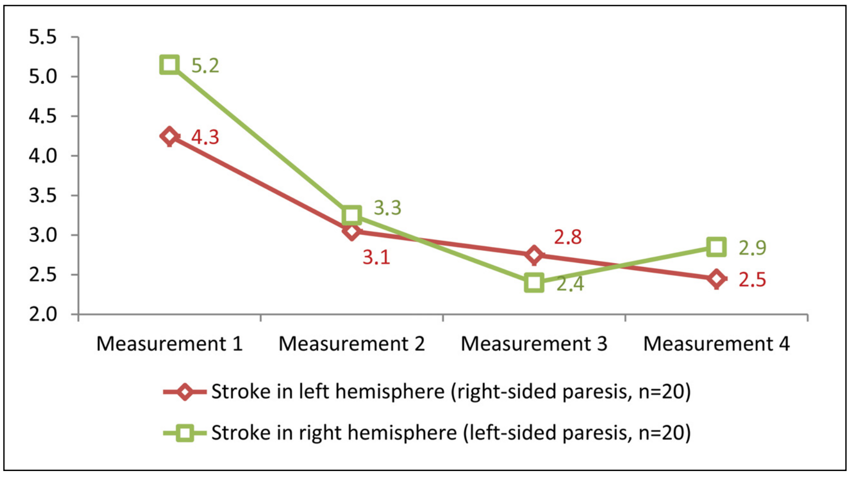

Figure 3

Average difference in weights A and B for particular measurements among sub-groups differing in stroke location (n=40)

differing in period of time from the incident. People who had suffered a stroke within the last two years were better at distributing body mass after the end of stimulation (Measurement No. 3, $p<0.001$), but this effect was not maintained when the intervention ceased. In turn, in people who had suffered stroke more than two years earlier, the changes were not so great, nonetheless, they also persisted after the end of stimulation (Figure 2).

Some insights are also provided by analysis conducted among subgroups differing in stroke location. Those who had suffered a stroke in the right hemisphere of the brain were better at distributing body mass after the end of stimulation (Measurement No. 3), but this effect was not maintained at the same level after cessation of interventions. On the other hand, people who had stroke in the left hemisphere (right side directly affected), were initially better at distributing weight better between the lower limbs; the change after 4 weeks was not so great but significant, and more importantly, despite the end of stimulation, the subjects maintained the therapeutic effects, even slightly improving their results (Figure 3).

Timed Up and Go test results

Before beginning physiotherapy, the average results of the subjects in the test qualified them to the group of patients at a high risk of falls (performance time over 19 seconds). In the study, a statistically significant differ-

Table 2

Significance tests for the Two-scale test (Measurement No. 1 vs. Measurement No. 4)

Significance tests	Sub-group	Measurement	Average	*SD*	Number of considered variables	Difference	*SD*	*t*	*df*	*p*
TUG	Total	Measurement No. 1	21.7	6.0						
		Measurement No. 4	17.0	4.2	34	4.8	4.4	6.4	33	**<0.0001**
TUG divided according to age	≤ 68 years	Measurement No. 1	21.0	6.0						
		Measurement No. 4	15.6	3.1	17	5.4	5.5	4.0	16	**<0.05**
	> 68 years	Measurement No. 1	22.5	6.1						
		Measurement No. 4	18.4	4.7	17	4.1	2.8	6.1	16	**<0.001**

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Table 2 (continued)

Significance tests	Sub-group	Measurement	Average	SD	Number of considered variables	Difference	SD	t	df	p
TUG divided according to side of paresis	Right-sided paresis (stroke in left hemisphere)	Measurement No. 1	21.9	6.1						
		Measurement No. 4	15.9	3.7	17	6.0	5.5	4.5	16	**<0.001**
	Left-sided paresis (stroke in right hemisphere)	Measurement No. 1	21.6	6.2						
		Measurement No. 4	18.1	4.5	17	3.5	2.5	5.9	16	**<0.0001**
TUG divided according to time from stroke	More than two years	Measurement No. 1	23.0	5.9						
		Measurement No. 4	18.6	4.7	14	4.4	3.2	5.1	13	**<0.001**
	Less than two years	Measurement No. 1	20.9	6.0						
		Measurement No. 4	15.8	3.4	20	5.1	5.1	4.4	19	**<0.001**

Measurement No. 1 – before beginning physical therapy; Measurement No. 4 – after a 2-week break following the completion of the performed physical therapy

ence in the measurements performed before and after the therapy were noted – and also within subgroups differing in age, time from illness and stroke location (Table 2).

Unlike the Two-scale test, in which the first stimulation affected significant improvement in loading the inferior lower limb, in the gait test, it caused an average change by 1 second. Only the next 4 weeks of therapy allowed for significant improvement in the obtained results, in which the time to cover the path took only 17.6 seconds. After a 2-week break, the obtained therapeutic effects continued to persist. By dividing the study population into subgroups of different ages, it was shown that elderly patients (over the age of 68) needed more time to perform the test, however, even in this subgroup, the final results obtained allowed the patients to be classified into the group of patients at an average risk of falls (Figure 4). It is worth noting that the cessation of stimulation caused slight deterioration of the results only in the older subjects.

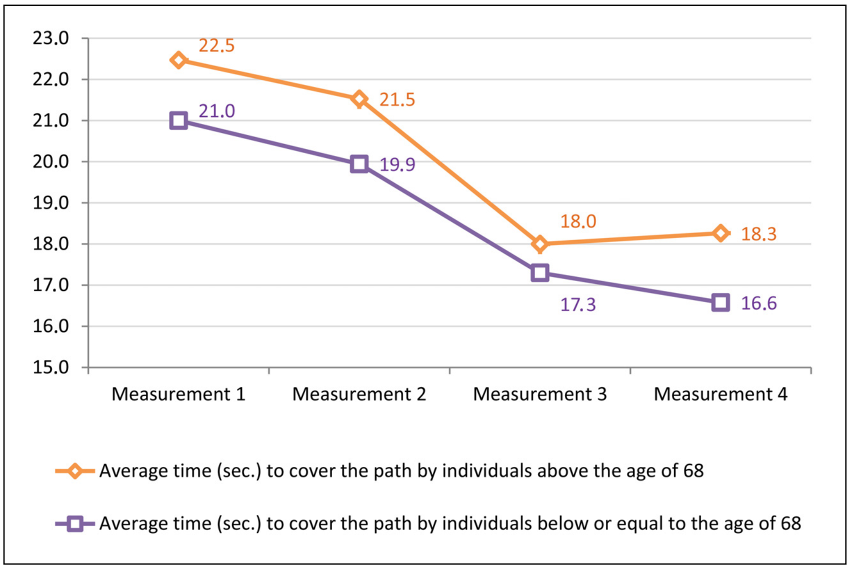

Figure 4

Average performance time of the Timed Up and Go test in individual measurements among the sub-groups differing in age

The test results analysed in subgroups that differ in time from the onset incident also showed a difference between the subgroups (Figure 5). People who suffered stroke relatively recently (less than 2 years earlier), performed the test tasks more quickly ($p<0.001$), however, sensory stimulation of the foot improved the results both in this group and in those who had an onset incident more than 2 years prior. The analysis of test results in subgroups with different stroke locations did not show significant differences between patients with left- or right-sided paresis.

Tinetti test results

The results of the Tinetti test performed before beginning physiotherapy qualified most of the subjects to the group of patients at a high risk of falls (result below 19 points). After sensory stimulation, improvement in balance and gait was achieved in all subjects, also when the results were analysed regarding subgroups with different stroke sides, time from stroke and at different ages.

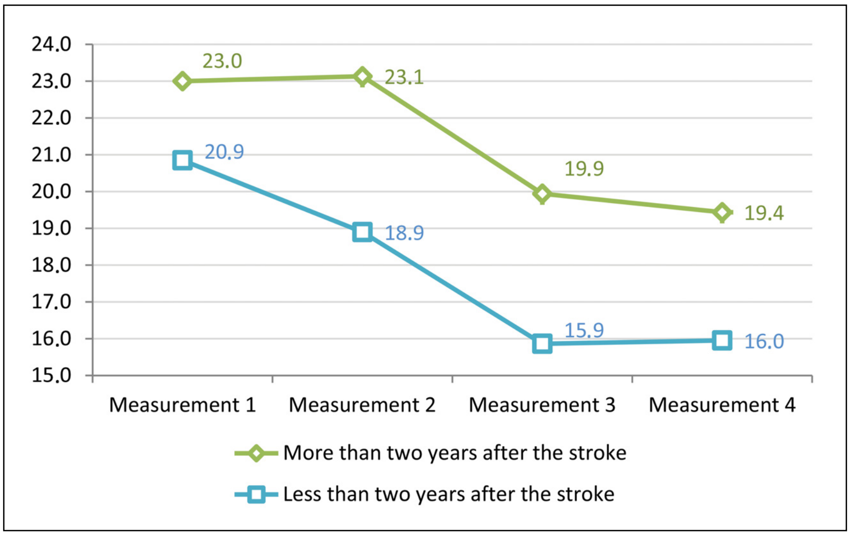

Figure 5

Average performance time of the Timed Up and Go test in individual measurements among the sub-groups differing in time from stroke

As in the case of the Timed Up and Go test, the results of sensory therapy did not provide as great effects after the first treatment as after a series of them. The similarity of results in these two tests also applies to the results of analyses in subgroups. In the Tinetti test, results were weaker for those older or with a longer period since stroke when performing balance or gait-related tasks (Figures 6 and 7).

The results of the analysis of subgroups with different sides of paresis showed that patients with left-sided paresis achieved better results (green curve on Figure 8). However, it was noticed that the therapy had similar effects in both groups: slight improvement after the first treatment and significant improvement after 4 weeks of treatment. In both groups, the effects persisted despite cessation of stimulation.

Table 3

Significance tests for the Tinetti test (Measurement 1 vs. Measurement 4)

Significance tests	Sub-group	Measurement	Average	*SD*	Number of considered variables	Difference	*SD*	*t*	*df*	*p*
Tinetti test	Total	Measurement No. 1	14.4	4.6						
		Measurement No. 4	18.3	4.0	40	-3.9	1.5	-16.6	39	**<0.001**
Tinetti test divided according to age	≤ 68 years	Measurement No. 1	15.2	4.6						
		Measurement No. 4	19.3	3.9	20	-4.2	1.5	-12.1	19	**<0.001**
	> 68 years	Measurement No. 1	13.7	4.5						
		Measurement No. 4	17.4	4.1	20	-3.7	1.4	-11.5	19	**<0.001**
Tinetti test divided according to side of paresis	Right-sided paresis (stroke in left hemisphere)	Measurement No. 1	15.1	4.6						
		Measurement No. 4	19.4	4.1	20	-4.3	1.5	-12.9	19	**<0.001**
	Left-sided paresis (stroke in right hemisphere)	Measurement No. 1	13.8	4.5						
		Measurement No. 4	17.3	3.8	20	-3.5	1.4	-11.2	19	**<0.001**
Tinetti test divided according to time from stroke	More than two years	Measurement No. 1	15.3	4.7						
		Measurement No. 4	19.2	4.1	23	-3.9	1.5	-12.7	22	**<0.001**
	Less than two years	Measurement No. 1	13.2	4.2						
		Measurement No. 4	17.2	3.7	17	-3.9	1.6	-10.4	16	**<0.001**

Measurement No. 1 – before beginning physical therapy; Measurement No. 4 – after a 2-week break following the completion of the performed physical therapy

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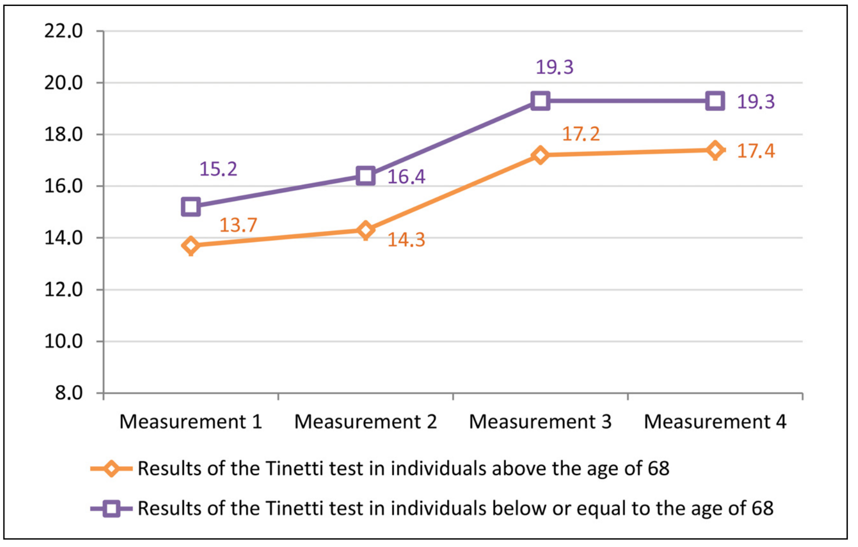

Figure 6
Results of the Tinetti test in particular measurements among sub-groups differing in age

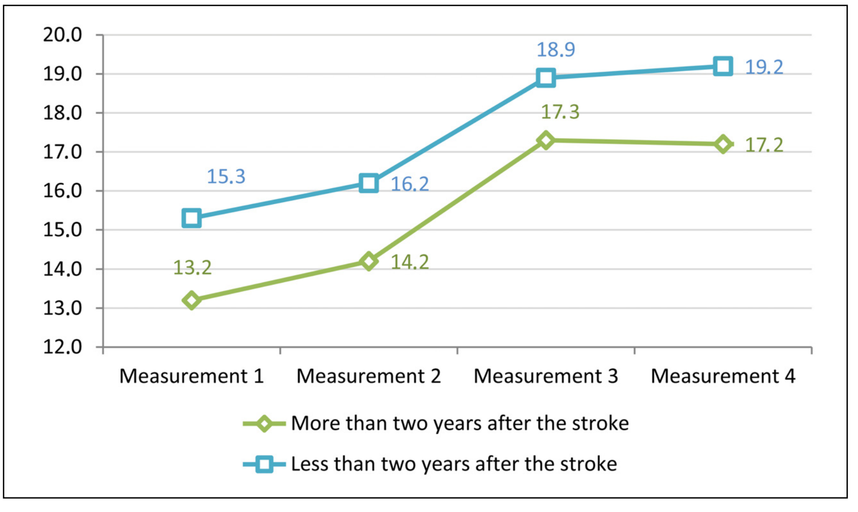

Figure 7
Results of the Tinetti test in particular measurements among sub-groups differing in time from stroke

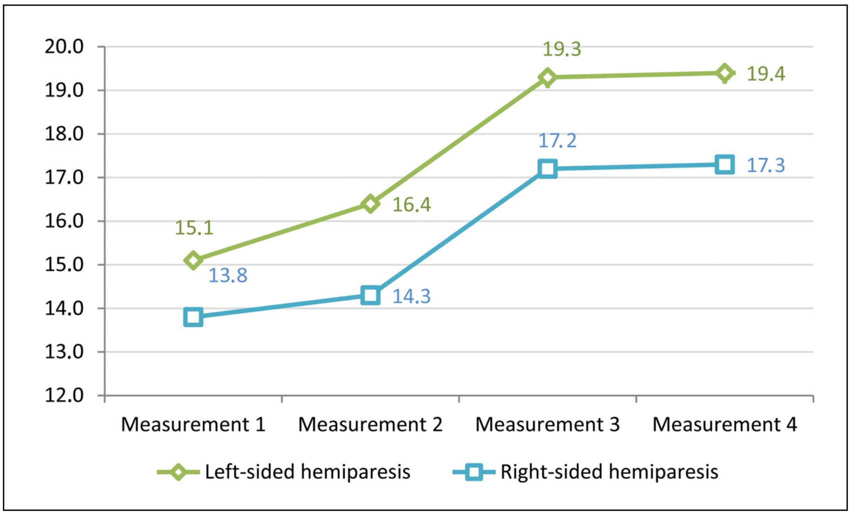

Figure 8
Results of the Tinetti test in particular measurements among sub-groups differing in stroke location

Considering the complexity of the Tinetti test, sensory stimulation of the feet resulted in the greatest improvement for the tasks directly related to taking on body mass by the lower limbs and stability in a standing position during static and dynamic tasks. The greatest improvement was recorded in the test with open eyes, the attempt to stand on a narrow base, balance after standing up and the knock-over attempt with closed eyes. The point increases for the particular tasks of the test are shown in Figure 9.

Correlations between test results

A very strong negative correlation was observed between the average results of the Tinetti test and the TUG test (r = -0.99, $p<0.001$). This means that patients shortening the time to overcome the distance of 3 meters, simultaneously, also improved the results of balancing tasks and those related to gait in the Tinetti test. Strong, negative correlations were also observed between the test results of the Two-scale test and both gait tests (r = -0.87, $p<0.001$). The improvement in weight distribution between the lower limbs was therefore strongly associated with the improvement of the results of dynamic activity, i.e. gait.

DISCUSSION

The aim of the study was to check the influence of therapy aimed at sensory stimulation of the foot in people with hemiparesis on weight distribution, balance and gait among this group of subjects. The obtained results allowed to observe a positive effect of sensory therapy performed in accordance with the Bobath concept for balance and gait functions. Loading of the directly affected lower limb immediately improved after the completion of stimulation, as illustrated by the results of the Two-scale test carried out after the first stimulation session. It can be assumed that the stimulation of pressure and deep sen-

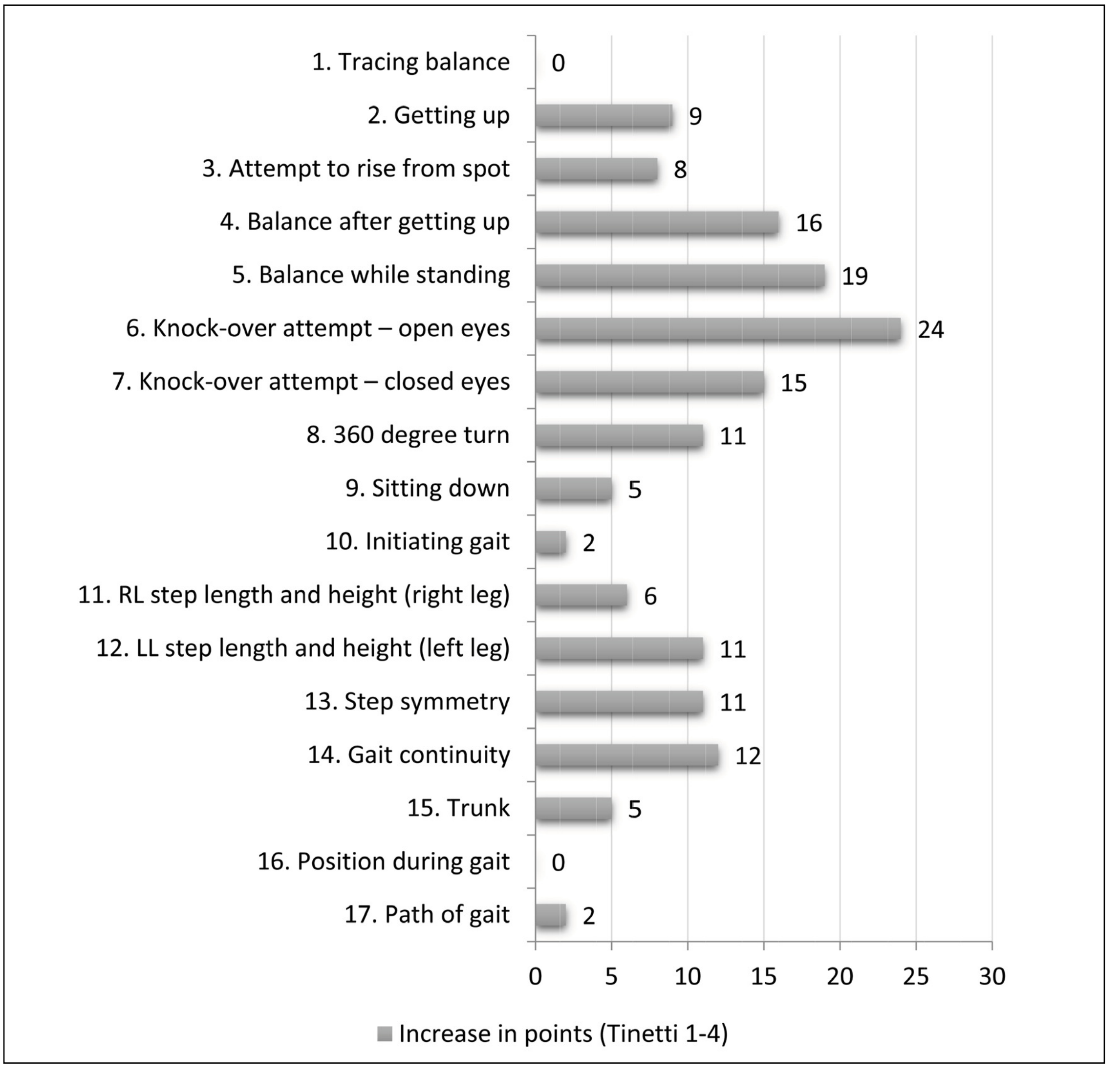

Figure 9

Increase in points obtained in the Tinetti test between Measurements No. 1 and 4 (n = 40)

sory receptors located in the muscles, tendons and joint surfaces resulted in a change of body scheme constructed on the basis of the sensory information currently received[19]. The nervous system receives a continuous stream of feedback from a wide range of external and internal receptors. It selects information related to the state of the body in face of planned and performed complex motor behaviours, as well as related to monitoring the course of currently performed activities[19]. The applied sensory stimulation of the foot combined with visual control of the patient and his/her concentration during experiencing the sensations, allowed for better integration of the inferior lower limb into the body scheme and improved motor performance which in this case was gait. As the authors point out, multisensory stimulation seems to be a promising therapeutic tool in stroke-induced sensory disorders, because information coming from different senses can improve detection, localization and responses to external stimuli, which reduces the disorder[6]. Our research proved that while weight distribution improved immediately, the improvement of gait test results required repeated training of this activity, but finally, a high correlation was found between test results. This is in line with the results of other reports in which the application of therapy based on the assumptions of the Bobath concept resulted in improvement of the results of gait tests in the studied post-stroke patients[20,21]. The applied somatosensory stimulation of the inferior foot could therefore act as reinforcement of sensory integration in the posterior parietal cortex responsible for performing locomotion guided by sight[22]. As it can be seen from the results of other studies, sensory stimulation of the foot performed using specialized inserts[23], platforms and vibration devices[24,25], or also electrotherapy[26], significantly affects the balance and gait function of people with neurological diseases.

The additional objective of our research was to check whether the location of the stroke affects the outcome of the applied sensory stimulation. For this purpose, patients with right- and left-sided paresis were compared. Persons with left-sided paresis were initially characterized by inferior weight distribution between the lower limbs. As a result of stimulation, this improved significantly, but compared to people with right-sided paresis, the effect of stimulation did not remain at the same level after its cessation. This situation can be explained by the difference between centres located in both hemispheres and their different function during reception, processing and reaction to sensory stimuli[27]. The right part of the brain focuses on visual impressions, processing information in an intuitive and simultaneous manner, first looking at the whole image, and then the details. The left side of the brain focuses on verbal stimuli, processing information in an analytical and sequential way, looking first at individual elements, assembling them together. The left side of the brain is responsible for reading, writing, counting and logical thinking; the right controls three-dimensionality, creativity and artistic sense[28]. Lateralization of specialized cortical functions such as speech or spatial orientation causes significant differences in the clinical image of a person after stroke of the right and left hemispheres of the brain. In general, speech disorders accompany damage to the left hemisphere, and cognitive disorders and depression to the right-side[29]. In ischemic stroke, worse functional abilities were noted in the case of damage to the left hemisphere compared to the right one[27]. However, this difference may have resulted from a longer hospitalization period (including physical therapy) in patients with stroke to the right hemisphere, which accompanying cognitive disorders, slow down the process of rehabilitation. However, Rynkiewicz et al.[30], and Laufer et al.[31] indicate that patients suffering from right-sided paresis reported better results of rehabilitation. Mortality rate was higher in the case of patients with hemorrhagic stroke in the right hemisphere within the three months following the incident, however, there were no differences in the functional performance of these subjects with different bleeding site[32]. Other authors also did not show the impact of brain damage location on the effects of rehabilitation[33,34], which demonstrates that an unequivocal resolution of this issue would require extensive, multi-centre studies. The limitation of this study is the lack of detailed data on the cause of the stroke (bleeding vs. embolism) and its exact location. The recruited patients were also characterized by a different period from the incident and history of rehabilitation. There was also a significant difference in age among both subgroups – people with left-sided paresis were significantly younger.

Taking the age of patients and the period from the incident into account, it was observed that younger people with shorter periods since the stroke showed relatively greater improvement. This result can be explained by more efficient brain mechanism functioning of young organisms, higher gene expression and higher concentration of substances released by the body as a consequence of ischemia, including growth factors contributing to the efficiency of plasticity mechanisms[35]. Different conclusions are presented by Bohannon et al.[36] who noticed that the age and time since the incident did not affect the tested balance. Due to the complexity of the brain and the multitude of connections between its structures, not many puzzles of how this organ functions during motion control have been solved. Obtaining an unambiguous answer to numerous questions, including those raised in the present study, requires further, multi-centre studies using technologically advanced diagnostic methods and accurate, sensitive and validated research tools.

CONCLUSIONS

1. Deep sensory stimulation consistent with the Bobath concept contributes to the improvement of motor function in patients with hemiparesis.
2. The effects of stimulation persist for 14 days after the completion of 20 therapeutic sessions.
3. The length of the post- period from onset may affect the patient's balance and gait function. Better results of stimulation are obtained by patients who subject themselves to it within less than two years after the stroke.
4. The patient's age influences the results of stimulation. Better effects are obtained by people under the age of 68.
5. The possible influence of damage location in the left or right hemisphere of the brain on the modification of the therapeutic results is noted. Better progress has been reported for patients with left-sided paresis.

Conflict of interest: none

Piśmiennictwo / References

1. Bolognini N., Russo C., Edwards D.J. The sensory side of post-stroke motor rehabilitation. Restor Neurol Neurosci 2016; 34(4): 571-586.
2. Szatkowska I. Pamięć operacyjna: integracyjna rola kory przedczolowej. Prz Psychol 1999; 42(1-2): 151-165.
3. Stein, B.E. (ed.). *The new handbook of multisensory processing.* MIT Press. Cambridge 2012.
4. Nudo R.J., Wise B.M., SiFuentes F., Milliken G.W. Neural substrates for the effects of rehabilitative training on motor recovery after ischemic infarct. Science 1996; 272(5369): 1791-1794. doi: 10.1126/science.272.5269.1791.
5. Buma F., Kwakkel G., Ramsey N. Understanding upper limb recovery after stroke. Restor Neurol Neurosci 2013; 31(6): 707-722.
6. Tinga A.M., Visser-Meily J.M., van der Smagt M., Nijboer T.C. Multisensory Stimulation to Improve Low- and Higher-Level Sensory Deficits after Stroke: A Systematic Review. Neuropsychol Rev 2016; 26: 73-91. doi: 10.1007/s11065-015-9301-1.
7. Sambo C.F., Vallar G., Fortis P., Ronchi R., Posteraro L., Forster B., et al. Visual and spatial modulation of tactile extinction: behavioural and electrophysiological evidence. Front Hum Neurosci 2012; 25(6): 217. doi: 10.3389/fnhum.2012.00217.
8. Shore S.E. Multisensory integration in the dorsal cochlear nucleus: unit responses to acoustic and trigeminal ganglion stimulation. Eur J Neurosci. 2005; 21(12): 3334-3348.
9. Bonan I., Chochina L., Moulinet-Raillon A., Leblong E., Jamal K., Challois-Leplaideur S. Effect of sensorial stimulations on postural disturbances related to spatial cognition disorders after stroke. Neurophysiol Clin 2015; 45(4-5): 297-303. doi: 10.1016/j.neucli.2015.09.006.
10. Lennon S., Hastings M. Key physiotherapy indicators for quality of stroke care Physiotherapy, 1996, 82 (12), 655-664:.
11. Bohannon R.W. Reference values for the timed up and go test: a descriptive metaanalysis. J Geriatr Phys Ther 2006; 29: 64-68.
12. Shumway-Cook A., Brauer S., Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed "Up & Go" Test. Phys Ther 2000; 80: 896-903.
13. Tinetti M.E., Doucette J., Claus E., Marottoli R. Risk factors for serious injury during falls by older persons in the community. J Am Geriatr Soc 1995; 43: 12141221.
14. Raine S. Defining the Bobath concept using the Delphi technique. Physiother Res Int. 2006; 11: 4-13.

15. Vaughan-Graham J., Cott C., Wright F.V. The Bobath (NDT) concept in adult neurological rehabilitation: what is the state of the knowledge? A scoping review. Part I: conceptual Perspectives. Disabil Rehabil 2015; 37: 1793-1807.
16. Michielsen M., Vaughan-Graham J., Holland A., Magri A., Suzuki M. The Bobath concept – a model to illustrate clinical practice. Disabil Rehabil 2017; 17: 1-13. doi: 10.1080/09638288.2017.1417496 [Epub ahead of print]
17. Vaughan-Graham J., Cott C. Phronesis: practical wisdom the role of professional practice knowledge in the clinical reasoning of Bobath instructors. J Eval Clin Pract 2017; 23: 935-948.
18. Cott C., Vaughan-Graham J., Brunton K. When will the evidence catch up with clinical practice. Physiother Can 2011; 63: 387-390.
19. Mizelle J.C, Oparah A., Wheaton L.A. Reliability of Visual and Somatosensory Feedback in Skilled Movement: The Role of the Cerebellum. Brain Topogr 2016; 29(1): 27-41. doi: 10.1007/s10548-015-0446-2.
20. Benito García M., Atín Arratibel M.Á., Terradillos Azpiroz M.E. The Bobath Concept in Walking Activity in Chronic Stroke Measured Through the International Classification of Functioning, Disability and Health. Physiother Res Int 2015; 20(4): 242-250.
21. Brock K., Haase G., Rothacher G., Cotton S. Does physiotherapy based on the Bobath concept, in conjunction with a task practice, achieve greater improvement in walking ability in people with stroke compared to physiotherapy focused on structured task practice alone?: a pilot randomized controlled trial?: a pilot randomized controlled trial. Clin Rehabil 2011; 25(10): 903-912.
22. Marigold D.S., Andujar J.E., Lajoie K., Drew T. Chapter 6-motor planning of locomotor adaptations on the basis of vision: the role of the posterior parietal cortex. Prog Brain Res 2011; 188: 83-100.
23. Corbin D.M., Hart J.M., McKeon P.O., Ingersoll C.D., Hertel J. The effect of textured insoles on postural control in double and single limb stance. J Sport Rehabil 2007; 16: 363-372.
24. Novak P., Novak V. Effect of step-synchronized vibration stimulation of soles on gait in Parkinson's disease: a pilot study. J Neuroeng Rehabil 2006; 3: 3-9.
25. Priplata A.A., Patritti B.L., Niemi J.B., Hughes R., Gravelle D.C., Lipsitz L.A., et al. Noise-enhanced balance control in patients with diabetes and patients with stroke. Ann Neurol 2006; 59(1): 4-12.
26. Tyson S.F., Sadeghi-Demneh E., Nester C.J. The effects of transcutaneous electrical nerve stimulation on strength, proprioception, balance and mobility in people with stroke: a randomized controlled cross-over trial. Clin Rehabil 2013; 27: 785-791.
27. Hedna V.S., Bodhit A.N., Ansari S., Falchook A.D., Stead L., Heilman K.M., et al. Hemispheric differences in ischemic stroke: is left-hemisphere stroke more common? J Clin Neurol 2013; 9: 97-102.
28. Shumway-Cook A.,Woollacott M.H. Motor Control: Translating Research into Clinical Practice. 4th Edition. Lippincott Williams & Wilkins Baltimore; 2009: 93-96.
29. Benejam B., Sahuquillo J., Poca M.A., Frascheri L., Solana E., Delgado P., et al. Quality of life and neurobehavioral changes in survivors of malignant middle cerebral artery infarction. J Neurol 2009; 256: 1126-1133.
30. Rynkiewicz M., Rogulska U., Czernicki J. Ocena zmian sprawności funkcjonalnej osób we wczesnym okresie po udarze mózgu. Prz Med Uniw Rzesz 2011; 2: 325-339.
31. Laufer Y., Sivan D., Schwarzmann R., Sprecher E. Standing balance and functional recovery of patients with right and left hemiparesis in the early stages of rehabilitation Neurorehabilitation and Neural Repair 2003; 17(4): 207-213.
32. Sato S., Heeley E., Arima H., Delcourt C., Hirakawa Y., Pamidimukkala V., et al. Higher mortality in patients with right hemispheric intracerebral haemorrhage: INTERACT1 and 2. J Neurol Neurosurg Psychiatry 2015; 86: 1319-1323.
33. Czernicki J., Woldańska-Okońska M. Wpływ strony niedowładu połowiczego na wyniki rehabilitacji chorych po udarach mózgu. Post Rehabil 1999; 13(1): 63-67.
34. Fedak D., Latała B., Otfinowski J., Zajdel K. Ocena wpływu fizjoterapii na równowagę w pozycji stojącej w grupie pacjentów po udarze mózgu, określona na podstawi badań posturograficznych. Acta Bio-Optica et Informatica Medica. Inż Biomeda 2010; 16(3): 208-211.
35. Johansson B.B. Brain plasticity and stroke rehabilitation: The Willis lecture. Stroke 2000; 31: 223-230.
36. Bohannon R.W., Smith M.B., Larkin P.A. Relationship between independent sitting balance and side of hemiparesis. Phys Ther 1986; 66(6): 944-994.

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