Biofeedback in rehabilitation of stroke patients

Biologiczne sprzężenie zwrotne w rehabilitacji chorych po udarze mózgu

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Key words
hemiparesis, balance platform, Barthel index

Abstract
Background and objectives. In patients after stroke there comes to body mass distribution disorders. It is an obstacle in reeducation of standing and walking as well as a limitation of the ability to perform everyday activities. The aim of the study was to assess the effect of balance platform training with the application of biofeedback on body mass distribution and the improvement of the efficiency of everyday activities performance in patients after stroke.
Material and methods. The investigated group included 25 subjects, who participated in the programme of rehabilitation consisting of platform training and physiotherapy. The comparative group were 14 subjects rehabilitated according to the established set of exercises excluding those on the balance platform. The training with the use of visual and auditory biofeedback, consisting of 10 repetitions, was performed every day 6 days a week. Both groups were subjected to the same training programme. The measurement of the feet pressure force on the balance platform in a standing position, neurological and physiotherapeutic examination and functional estimation of everyday activities according to Barthel index, were performed in every patient before and 18 days after the training. For the training and the measurement of the pressure force ERBE balance platform was used with Windows Physio-Feedback System.
Results and conclusions. In both groups statistically significant improvement of functional conditions and body mass distribution were observed. The training of hemiparetic patients on the force platform with the application of biofeedback affects the change in the value of pressure force of lower extremity to the values observed in healthy subjects. The increase in relative lower extremity pressure on the paretic side was 5 times higher in the group with biofeedback than in the group without it.

Słowa kluczowe
niedowład połowiczy, platforma balansowa, indeks Barthel

Streszczenie
Założenia i cele. U chorych po udarze mózgu występują zaburzenia dystrybucji masy ciała, które stanowią przeszkodę w reedukacji stania i chodzenia oraz ograniczają sprawność wykonywania czynności dnia codziennego. Celem pracy była ocena wpływu treningu na platformie balansowej z zastosowaniem biologicznego sprzężenia zwrotnego na dystrybucję masy ciała i poprawę sprawności wykonywania czynności w życiu codziennym u chorych po udarze mózgu.
Materiał i metody. Grupę badaną stanowiło 25 osób, które uczestniczyły w programie rehabilitacji składającym się z treningu na platformie, ćwiczeń indywidualnych oraz fizykoterapii. Grupę porównawczą stanowiło 14 osób usprawnianych według ustalonego programu bez ćwiczeń na platformie balansowej. Trening z zastosowaniem wzrokowego i słuchowego biologicznego sprzężenia zwrotnego stanowiło 10 powtórzeń, prowadzony był raz dziennie. Program realizowany był przez 6 dni w tygodniu. U wszystkich badanych przeprowadzono: pomiar siły nacisku kończyn na platformie balansowej w pozycji stojącej, badanie neurologiczne i fizjoterapeutyczne oraz ocenę funkcjonalną czynności dnia codziennego według indeksu Barthel. Badanie odbywało się przed rozpoczęciem treningu i po 18 dniach treningu. Do pomiaru siły nacisku oraz treningu zastosowano platformę balansową ERBE współpracującą z programem komputerowym dla Windows Physio-Feedback-System.
Wyniki i wnioski. W obu grupach uzyskano znamienną statystycznie poprawę stanu funkcjonalnego oraz dystrybucji masy ciała. Trening chorych z niedowładem połowiczym na platformie balansowej z zastosowaniem biologicznego sprzężenia zwrotnego wpływa na zmianę wartości rozkładu sił nacisku kończyn dolnych do wartości obserwowanych u osób zdrowych. Przyrost względnego nacisku kończyny dolnej po stronie z niedowładem jest około 5 krotnie większy przy połączeniu indywidualnego treningu z ćwiczeniami z zastosowaniem biologicznego sprzężenia zwrotnego niż w grupie usprawnianej według takiego samego programu bez biologicznego sprzężenia zwrotnego.

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Introduction

The biofeedback (BFB) method involves visualisation and conscious regulating a given activity. The idea of biofeedback-assisted training is to develop full control over physiological processes. In the sixties of the 20th century, in the Langley-Porter Neuropsychiatric Institute of San Francisco, a term “training of control of the self-regulating system by means of a biophysiological feedback” was used to describe the BFB. Currently, biofeedback is used in teaching relaxation and rapid memorising, in shaping the posture and profile during biological regeneration. In combination with electromyography, it helps in normalising muscle tone and muscular re-education. It is more and more frequently introduced into the programmes of exertion urinary and faecal incontinence treatment[1,2]. The EEG biofeedback method is used in such conditions as syndromes of psychomotor hyperactivity and chronic fatigue, in the therapy of sleep disturbances, in migraine and in the therapy of substance dependence. The BFB method enables correcting cerebral dysfunction resulting from abnormal development or diseases of the central nervous system. In the BFB therapy, the activities are visualised in a form of linear or column plots, altering sound intensity and tone-colouring, number and colour changes of lighted diodes dependent on the degree of task performance. Based on the feedback loop, the patient learns to consciously control the activity adequately to the information being obtained.

As a result of cerebral stroke, there are functional deficits that require rehabilitation in the possibly earliest time following stroke occurrence, according to the guidelines of the Helsingborg Declaration. Designing the therapeutic programme after stroke must be preceded by detailed diagnostics. Special attention should be paid to disturbances of body mass distribution, pusher syndrome and unilateral neglect syndrome and other neurological and neuropsychological deficits that affect hospitalisation and rehabilitation duration[3,4,5]. For this evaluation and treatment monitoring in post-stroke patients, clinical tests, stroke scales, quality of life scales and modern methods of e.g. measurement of body mass distribution are used[6,7]. Based on these methods, rehabilitation programmes adjusted to individual patient’s clinical status are elaborated.

Central nervous system damage induces disturbances of body mass distribution, spatial orientation and balance. In patients with hemiparesis, locomotion and performance of basic activities of living are compromised. The aim of rehabilitation is to restore patient’s best possible functioning. Following stroke, an important phase of rehabilitation involves restoring proper body mass distribution and balance constituting the basis of stance, walking and self-service learning. To achieve this, it is indicated to use most modern therapeutic methods based on the biofeedback principle.

The aim of the study was to assess the effects of biofeedback-assisted training on a force platform on body mass distribution and improvement in the performance of activities of daily living in patients with central nervous system lesions.

Material and methods

Thirty nine patients aged 34 to 73 years (mean age: 58 ±8 years) hospitalised in the Department of Rehabilitation with Day Unit at the Medical University of Łódź in the University Departmental Hospital No 5 were enrolled to the study. The inclusion criterion for the study was hemiparesis due to the first ever cerebral stroke. All participants were trained using the biofeedback for the first time in their lives. Right-sided hemiparesis was present in 18 patients, left-sided hemiparesis – in 21 patients. Mean duration of hospitalisation was 27 ±8 days. Functional evaluation assessed using the Barthel index was 13 ±4 on admission. Patients were randomised into the biofeedback group and the control group. Two hospital rooms, a 2- and a 3-bed, were prepared for the biofeedback study; patients concomitantly hospitalised in the department in the remaining rooms served as controls. The evaluated group comprised 25 persons, who participated in a rehabilitation programme consisting of force platform training, individual exercises and physiotherapy. Measurement of pressure force exerted by the lower extremities onto the platform was performed in the erect posture without any support. The time needed to perform a measurement was 3 seconds. The training on the force platform comprised 10 cycles according to the formula 20 seconds/6 sinus (Figure 1). Each cycle consisting of correct passing the cursors through the sinusoid of 6 positive inclinations, performed without mistakes, lasts 20 seconds, inter-cycle interval is 5 seconds. Minimum performance time of one training without mistakes is 4 minutes 5 seconds. In the evaluated group and the control group, training duration was not restricted and ranged from 5 minutes 30 seconds to 12 minutes. The training was credited after performance of 10 cycles.

The training involves shifting the load from one limb onto the other

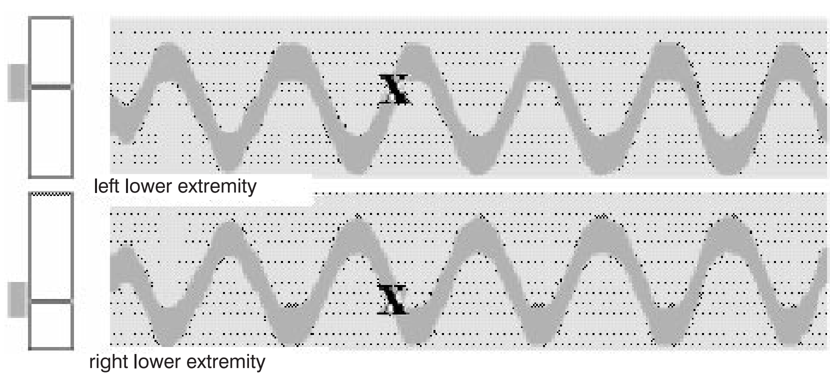

Figure 1

One of cycle of training on force platform according to 20 seconds/6 sine (X- cursor of training)

Table 1

Characteristics of groups		
	Biofeedback group (N=25)	**Control group (N=14)**
Age, mean ± SD (years) range	57 ±8 39–72	59 ±13 34–73
Number of females Number of males	7 18	6 8
Right-sided hemiparesis Left-sided hemiparesis (number of patients)	12 13	6 8
Duration of hospitalisation (number of days) mean ± SD range	 26 ±7 18–51	 29 ±8 18–41

in such a way that the cursors move over the demarcated path (sinusoidal curves). During the training, patient's mistake, that is each "slipping" of the cursor off the demarcated line, was signalled by a sound (auditory biofeedback) and stopping the cursor on the monitor screen (visual biofeedback). Upon correction of the pressure distribution of the lower limbs by the patient, the sound signal was switched off and the cursor returned to the appropriate position and the training was resumed. The control group comprised 14 persons undergoing rehabilitation according to the same standard programme of individual exercises and physiotherapy as the evaluated group, but without the exercises on the force platform (group characteristics listed in the table 1). In both groups, the programme was conducted 6 days a week. In the biofeedback or the control group, there were no patients with concomitant unilateral neglect and/or pusher syndromes.

In all participants, the following procedures were performed: measurement of the pressure force exerted by the lower limbs onto the force platform in the standing position, neurological and physiotherapeutic examination and functional assessment of activities of daily living using the Barthel index. The assessment was performed prior to commencing the training and after training termination. For the pressure force measurements and the training, a force platform ERBE with Physio-Feedback-System software for Windows, constituting a set of 2 platforms enabling recording of pressure force exerted by both extremities was used.

Results

Results of the study are presented as arithmetic mean, standard deviation and median values. The non-parametric Wilcoxon signed rank test for paired variables was used in the statistical analysis. The level of statistical significance for the used statistical test was set at $\alpha=0.05$.

There was no statistically significant difference in the functional status or the pressure force distribution of the lower extremities between the biofeedback and the control group prior to the rehabilitation ($p>0.05$).

Functional status according to the Barthel index was compared between the patients in the evaluated and the control group. Functional assessment in both groups prior to and after the rehabilitation is presented in the table 2.

Based on the performed analysis, a statistically significant improvement in the functional status assessed using the Barthel index was found within both groups. Comprehensive rehabilitation programmes, with and without biofeedback, both induce an improvement in the functional status in post-stroke patients with hemiparesis.

Based on the measurements performed on the force platform, values of relative pressure force of the lower limbs on the hemiparesis side were calculated according to the methodology published previously, with the assumption that the sum of the left and right extremity pressure force equals 1 [8]. Table 3 lists relative pressure force values for the paretic extremity before and after the rehabilitation cycle.

Within both groups, mean value of the relative pressure force of the paretic extremity significantly increased after the rehabilitation. In the biofeedback group, the distribution approached the symmetrical distribution, whereas in the control group, body mass distribution asymmetry was still present.

Increments of the relative pressure force of the paretic lower extremity were compared between the biofeedback and the control group (Table 4).

It is noticeable that the degree of the paretic limb relative pressure force increment was 75% of the baseline value in the evaluated group, while in the control group – 15% of the baseline value. We found that the increment of the relative pressure force exerted by the paretic lower extremity was significantly greater in the biofeedback group.

Discussion

Discovering of the brain plasticity phenomenon and the introduction of modern diagnostic and therapeutic methods to the rehabilitation have created a basis for elaboration of novel rehabilitation methods in the therapy of post-stroke patients. The assessment of lower limbs loading symmetry and of balance disturbances as well as the analysis of the effects of therapy in post-stroke patients using modern methods is important in contemporary rehabilitation[9,10,11,12,13]. Two scales or force platforms are used for

Table 2

Functional condition according to Barthel index				
		Before rehabilitation	**After rehabilitation**	**p value**
Biofeedback group	mean ± SD median	13,9 ±3,7 14	15,8 ±2,9 17	<0,005
Control group	mean ± SD median	12,5 ±4,2 14	15,1 ±3,8 18	<0,005

Table 3

Pressure force of lower extremity on the paretic side				
		Before rehabilitation	**After rehabilitation**	**p value**
Biofeedback group	mean ± SD median	0,28 ±0,08 0.30	0,49 ±0,02 0.49	<0,005
Control group	mean ± SD median	0,26 ±0,09 0,25	0,30 ±0,07 0,28	<0,005

Table 4

Increment of the relative force of lower extremity on the paretic side			
			p value
Biofeedback group	mean ± SD	0,21 ±0,08	<0,005
Control group	mean ± SD	0,04 ±0,02	

the assessment of lower extremities pressure distribution in patients with hemiparesis[10,14,15]. Pyoria et al.[16] evaluated the symmetry of body mass distribution in the standing position using a force platform with a triangular base. For the clinical assessment of balance, they used the Functional Standing Balance (FSB) scale, consisting of: assessment using the two scales test, assessment of balance during and without motion. The authors found that the correlation between the measurement of body mass distribution using the FSB scale and the lateral symmetry assessed on the force platform was 0.44 for patients with recent stroke (up to 3 weeks) and 0.52 for patients, who had had a stroke more than 6 months before the testing. They indicated clinical usefulness of balance assessment methods, especially of the FSB scale. Body mass distribution assessment in post-stroke patients with hemiparesis, with the use of the above devices, allows a statement that the body weight is shifted towards the non-paretic limb and the gait is characterised by asymmetry and a reduced speed[17,18]. In our material, mean loading of the paretic extremity was less than twice as low as that of the non-paretic limb prior to the rehabilitation. We applied the rehabilitation programme achieving a significant improvement in body mass distribution within both groups. However, this change of symmetry direction was more pronounced in the group exercising using visual and auditory biofeedback. Similarly, Wong et al.[19] demonstrated that visual and auditory biofeedback training has a positive effect on the symmetry during stance in patients with hemiparesis. Kwolek and Drużbicki[20] also showed a positive role of biofeedback in the rehabilitation of post-stroke patients. Barclay-Goddard et al.[21] did not find evidence that biofeedback and force platform assisted trainings clinically improve the balance during standing, motion and walking. However, they found that these trainings do improve standing symmetry without concomitantly affecting postural sway. Application of biofeedback enables an earlier trunk control and is a useful component of physiotherapy in the rehabilitation of post-stroke patients[22]. Abnormal body mass distribution during stance in post-stroke patients is a cause of falls; therefore, Nyberg et al.[23] list the teaching of fall prevention as a very important element of the rehabilitation. Cheng et al.[24] assessed the effects of feedback-assisted training of body mass distribution in the prevention of falls in post-stroke patients. They demonstrated that this training is effective and may reduce the number of falls. In our studies, biofeedback-assisted training positively influences the performance of activities of daily living as assessed using the Barthel index; however, we found that it was not more efficacious than the standard rehabilitation programme without the biofeedback. Lee et al.[25] also demonstrated a positive effect of biofeedback training on the improvement of functional and clinical status after stroke. In case of auditory biofeedback trainings, Engardt[26] demonstrated an improvement in the symmetry of lower limbs loading distribution, however, did not find its durability after 33 months. Based on the presented results, it can be concluded that use of biofeedback-assisted training not only ameliorates the symmetry of loading the lower extremities, but, in contrast to the rehabilitation without biofeedback, brings this symmetry closer to the distribution observed in healthy persons. This is very important, as during the whole process of rehabilitation, teaching the patient to balance the body mass during stance is a critical point of time and should precede the phase of learning to walk and to perform self-service activities. This task may be completed by application of modern rehabilitation methods supplemented with biofeedback training. Concomitant use of exercises, kinesitherapeutic methods and modern biofeedback trainings undoubtedly positively influences the outcome of the therapy; however each of these methods requires repetition and consolidation of the achieved effects.

Conclusions

1. The biofeedback-assisted training on the force platform in patients with hemiparesis results in a change of the values of lower extremities pressure force distribution towards the values observed in healthy persons.
2. The increment of the relative pressure force of the paretic lower extremity when using the combined individual and biofeedback training is approximately 5 times greater than that achieved using the same individual programme without the biofeedback.

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