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## BODY BALANCE IN PATIENTS WITH SYSTEMIC VERTIGO AFTER REHABILITATION EXERCISE

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The aim of this paper was to characterize structural balance of the body in people with systemic vertigo after applying rehabilitation exercise, such as motor-visual coordination on a posturographic platform and balance exercise. Physiotherapeutic procedures were carried out in a group of 12 people, aged 25-60 years suffering from vertigo. The evaluation of body balance in the standing position was performed by means of recording of postural sways based on force-plate posturography. The examination was performed before and after the rehabilitation program. Standard tests were done, with eyes open, eyes closed, and with conscious visual control-biofeedback. Patients with vertigo underwent a month-long therapy, which included: exercise of motor-visual coordination on a posturographic platform and balance exercise, which consisted of repeated visual, vestibular, and somatosensory stimulation for conscious postural control. The rehabilitation program resulted in a decrease of the range of sways, improved visuomotor coordination and thus also improved balance.

*Key words: body balance, posture control, rehabilitation, stabilography, vertigo*

### INTRODUCTION

Vertigo and balance disorders of vestibular origin are one of the most common otolaryngological problems encountered by general practitioners (1, 2). A systematically increasing number of people suffering from balance disorders has become one of the main issues in modern medicine, and the most dangerous event accompanying the disturbances are falls (3-5). The studies carried out in

recent years show that vertigo may occur in 18% of people over 60 years of age and in 25% of the general population, which constitutes a widespread problem (1-6). The majority of vertigo cases are of peripheral origin (7). Vertigo may give an illusion of motion, usually of turning around or spinning of the surroundings, and that, together with the sense of unsteadiness (9), is one of the main factors affecting the quality of life (10-12). Subjective and objective symptoms of damage of the labyrinth are reduced in the process of vestibular compensation. It results from spontaneous activity of another subsystems, which are engaged in maintaining balance. Visual, vestibular, and somatosensory signals coming from those subsystems are constantly analyzed in the central nervous system (13-16).

For many years the pharmacological treatment of vestibular imbalance has been combined with physiotherapeutic procedures (17). The proposed physiotherapeutic programs for people with vertigo include visuomotor coordination and balance exercise, which consists of repeated visual, vestibular, and somatosensory stimulation for conscious control of body balance (15). The choice and purpose of the exercise should be preceded by evaluation of the balance system by means of the examination of horizontal sways of the body measured as two-dimensional movement of center-of-foot pressure (COP) as a function of time. In the sagittal plane, shifting of COP is caused by the activity of muscles cooperating with the ankle joints (ankle's strategy), whereas in the frontal plane by the activity of adductors and abductors of the hip joints (hip's strategy) (18). The most commonly known method of assessing the balance system's efficiency in both healthy and ill subjects is stabilography (19-24). The method makes it possible to evaluate the external symptoms of posture control by measuring the magnitude of body sways (25). The activity of each posture controlling factor, maintaining the balance, may be disturbed by disease or aging. Balance disorders belong to structural changes having to do with structural steadiness. However, the main feature of the posture control system is the choice of strategy, in other words, a certain way of action when disturbances occur (26).

The aim of this paper was to characterize the structural balance of the body in people with systemic vertigo after applying rehabilitation exercise, such as exercise of motor-visual coordination on a posturographic platform and balance exercise.

## MATERIAL AND METHODS

### *Subjects and body balance evaluation*

The research group consisted of 12 people (11 women, one man) aged 25-60 ( $46.8 \pm 12.6SD$ ) with vertigo caused by weakening of the vestibular excitability, who were diagnosed at the Clinic of Otolaryngology of Wroclaw Medical University in Wroclaw, Poland. The medical history of each patient was taken and each patient was laryngologically examined, pure tone threshold audiometry

was also performed together with standard videonystagmographic examination and bi-calorie test according to Fitzgerald-Hallpike.

The posture control examination and physical rehabilitation were carried out in the Functional Examination Laboratory for internal diseases (ISO 9001:2001 Certificate) at the Faculty of Physiotherapy of the University of Physical Education in Wrocław, Poland. The research program applied was approved by the Senate Committee for Ethics of Scientific Research of the University of Physical Education in Wrocław, Poland.

The evaluation of body balance in the standing position was performed by means of recording of postural sways based on force-plate posturography, using a Posturograf System, Pro-Med (Poland). The following standard tests were performed:

- with eyes open (unrestrained standing position),
- eyes closed (forced standing position),
- with conscious visual control (forced standing position) - biofeedback.

The test was carried out twice, before and after the rehabilitation, with provided peace, quiet, concentration, and with full assistance.

We selected the following measures of the COP shifts in the two-dimensional support surface:

- *Area* – stabilogram's surface area in mm<sup>2</sup>,
- *Total Length* – total length of the stabilogram in mm,
- *LR length* – total length of left-right (L-R) motion in mm – characterizes sways in the frontal plane,
- *FB length* – total length of forward-backward (F-B) motion in mm – characterizes sways in the sagittal plane,
- *Coordination (%)* – describes the efficiency of posture self-correction while observing a point projected on a screen, keeping it inside a fixed square visible on the screen (biofeedback),
- *ICOP (%)* – COP index is a measure of shares of COP shifting in the sagittal and frontal plane in the total length of stabilogram – a simple formula proposed by M. Mraz of the University of Physical Education, in Wrocław, Poland defines ICOP index as:

$$ICOP = 100 \times \frac{FB \text{ length} - LR \text{ length}}{FB \text{ length} + LR \text{ length}}$$

Calculation of the COP index made it possible to choose the strategy of body balance control in the standing position, assuming that:

- ICOP = 0 – no domination of COP shifting in the planes,
- ICOP > 0 – ankle strategy (dominating shifting of COP in the sagittal plane),
- ICOP < 0 – hip strategy (dominating shifting of COP in the frontal plane).

### *Methods of Physiotherapy*

The patients suffering from vertigo underwent a month-long therapy, which included visuomotor coordination exercise on the posturographic platform and balance exercise. The exercise sessions took place every second week and lasted about 60 min. Individualized balance exercise were carried out independently every day at home. The visuomotor coordination exercises on the posturographic platform consisted of visual stimulation of the balance control system in a feedback loop. Application of conscious control of COP for posture self-correction took place in static and dynamic conditions using gradually increasing difficulty of the exercise. The patient examined was consciously moving their COP point so as to reach a given location or the sequence of locations in a proper time (*Fig. 1*). The duration of visuomotor coordination exercises was 10 min.

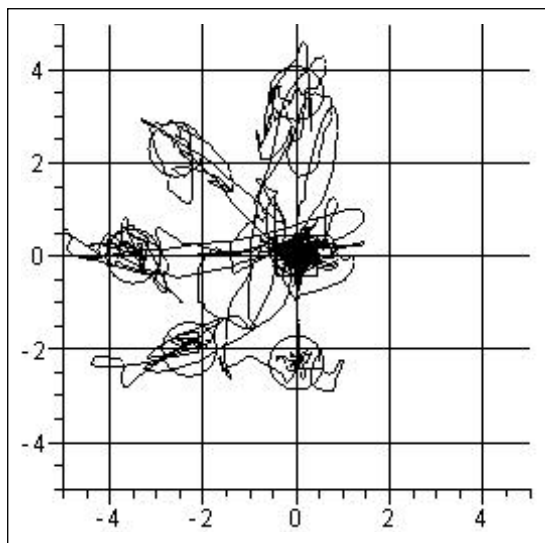


Fig. 1. Example of a five-object system located in left quarters of the system of coordinates in visuomotor coordination exercise on the posturographic platform (biofeedback).

The balance exercise carried out individually at home was as follows:

*First and second week of the therapy.* On all fours:

- balancing one's body in various directions and regaining the initial position,
- reduction of the support points at first by detaching one limb (upper or lower) from the surface and later by detaching two limbs (upper and lower),
- moving the unsupported limb or limbs.

Exercise in the kneeling position consisting of balancing one's body in various directions.

Exercise in the straddle position and in lunge balancing one's body in various directions.

*Third week of the therapy.* The exercise practiced in the first and second week carried out on an unstable surface (7.5 cm sponge).

*Fourth week of the therapy.* The exercise practiced in the third week and balance exercise in the standing position on the balance platform, in both planes.

All exercise was repeated 3-4 times, always with visual control and assistance. At home, exercise on the sponge surface and balance platform was not performed.

### *Statistical analysis*

The results were statistically analyzed by means of Statistica 8.0 software by Statsoft. For variables of the body's stability that did not pass a test for the normality (Kolmogorov-Smirnov) of distribution, a non-parametric Wilcoxon test and a Spearman correlation analysis were applied. Standard level of  $P \leq 0.05$  was applied for rejection a null hypothesis. The Scheffe test was employed to check the total significance level for all conditions of the body balance examination in the standing position (eyes open, eyes closed, biofeedback).

## RESULTS

Variables of body balance in people with vertigo obtained during the examinations before and after the rehabilitation program were subjected to

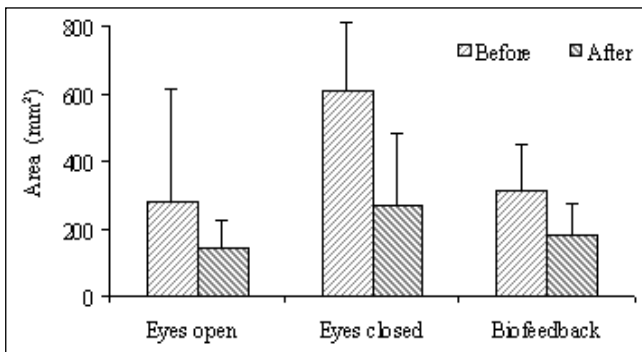
statistical analyses. Physiotherapy resulted in a significant decrease of the range of postural sways in the image of stabilogram's surfaces, while maintaining body balance in the standing position with eyes open ( $P=0.019$ ), eyes closed ( $P=0.004$ ), and with feedback ( $P=0.002$ ) (*Fig. 2*).

The evaluation of body balance in the forced standing position with visual control for posture self-correction (biofeedback) showed a significant improvement of visuomotor coordination ( $P=0.002$ ). The coordination parameter increased significantly (*Fig. 3*).

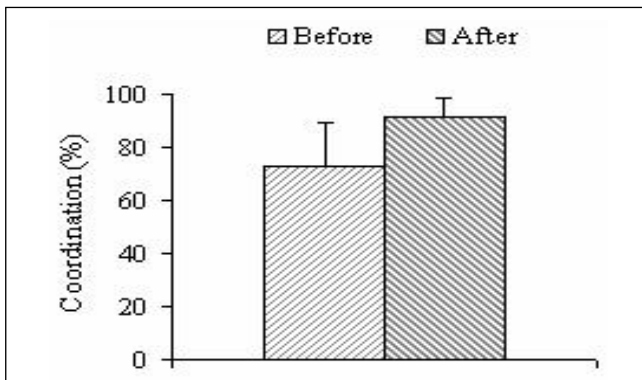
The total length of the stabilogram showed no significant change resulting from the rehabilitation in both unrestrained (eyes open) and forced standing positions (eyes closed, biofeedback) (*Fig. 4*).

No significant difference of the stabilogram's length after the physiotherapeutic program was observed in the frontal (L-R) or sagittal (F-B) plane, except for the test in the forced standing position with biofeedback, where there was a statistically significant decrease of the stabilogram's length in the frontal plane (L-R) ( $P=0.004$ ) (*Fig. 5*).

Spearman's correlation tests of the total length of stabilogram and the L-R and F-B lengths before and after the therapy (separately for each test) showed the following results:



*Fig. 2.* Comparison of the mean values of the stabilogram's surface area before and after the physiotherapeutic program.



*Fig. 3.* Comparison of the mean values of the coordination parameter before and after the physiotherapeutic program.

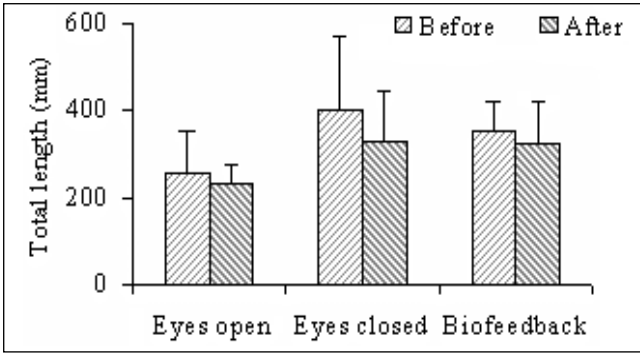


Fig. 4. Comparison of the mean values of the stabilogram's total length before and after the physiotherapeutic program.

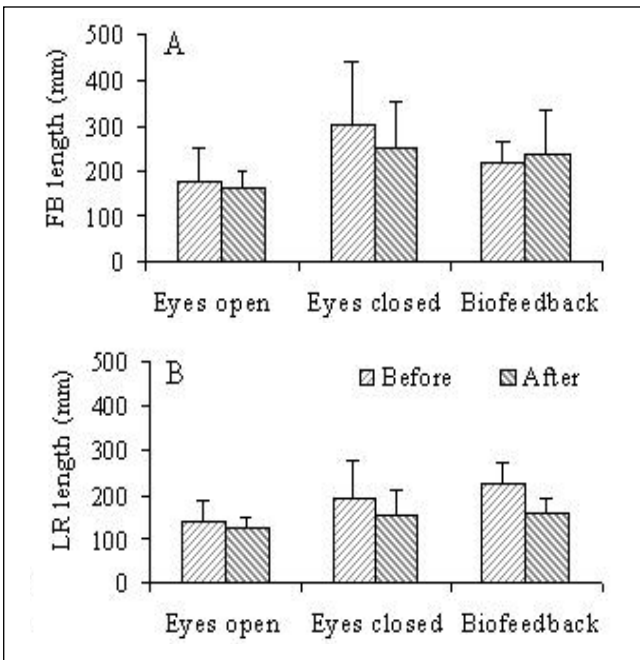


Fig. 5. Comparison of the mean values of the stabilogram's length in the sagittal F-B (Panel A) and frontal L-R (Panel B) plane before and after the physiotherapeutic program.

- Tests with the eyes open:

After the rehabilitation program, there was a significant correlation between the total length and the L-R length of stabilogram ( $r=0.74$ ) and nearly a full correlation between the total length and the F-B length of stabilogram ( $r=0.92$ ).

- Tests with the eyes closed:

After the rehabilitation program, there was a slight decrease of the correlation between the total length and the L-R length of stabilogram ( $r=0.53$ ). However, the correlation between the total length and the F-B length of stabilogram still showed nearly a full correlation ( $r=0.98$ ).

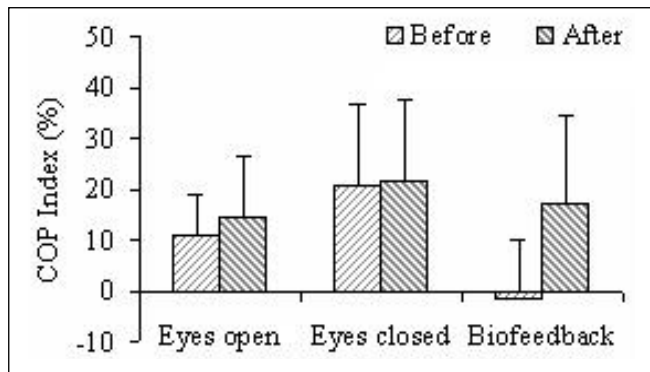


Fig. 6. Comparison of the mean values of the center-of-pressure index before and after the physiotherapeutic program.

- Tests with biofeedback:

After the rehabilitation program, the correlation between the total length and the L-R length of stabilogram became insignificant ( $r=0.26$ ). Yet, the correlation between the total length and the F-B length of stabilogram increased ( $r=0.93$ ).

The observed changes in the correlations between the total length of stabilogram and its lengths in the sagittal and frontal planes are far better illustrated by the introduced COP index, which allowed examining the sways in COP in both planes. Before the therapy, the mean values of ICOP in the unrestrained standing position ( $10.9 \pm 8.1$ ) and in the forced standing position with eyes closed ( $20.8 \pm 16.0$ ) showed the predominance of COP sways in the sagittal plane, which points to the ankle strategy. However, the mean value of ICOP in the forced standing position with biofeedback ( $-1.2 \pm 11.2$ ) reflected the predominance of COP sways in the frontal plane, which points to the hip strategy. After the therapy, the mean values of ICOP in the unrestrained standing position with eyes open ( $14.8 \pm 11.6$ ), in the forced standing position with eyes closed ( $21.8 \pm 15.8$ ), and in the forced standing position with biofeedback ( $17.3 \pm 17.3$ ) showed the predominance of COP sways in the sagittal plane, which indicates the ankle strategy (Fig. 6).

ICOP in the forced standing position with biofeedback showed a significant change after the therapy ( $P=0.009$ ) indicating the ankle strategy, and thus the predominance of COP sways in the sagittal plane in accordance with the remaining examinations – with the eyes open and closed. Only in the control examination with biofeedback did the ICOP value significantly differ from the other examinations, both control ones and those after the therapy.

## DISCUSSION

Subjective and objective symptoms of damage of the labyrinth are reduced in the process of vestibular compensation resulting from spontaneous activity of the central nervous system, which is enforced by physiotherapy. It is well known that

balance disorders may be compensated by increased, spontaneous activity of another subsystem or by applying repeated visual stimulation (biofeedback) (13,14). The results of Bronstain (27) and of Hafström et al (28) suggest that the vestibular system and proprioceptors may take over the role of sight in balance control when visual information is decreased or unavailable (27, 28). Similar conclusions about positive usage of biofeedback in physiotherapy of systemic vertigo were drawn by Hahn et al (15). All these studies state that physiotherapy helps patients fight fear, prevents disorientation, and helps regain coordination and body balance (13-15, 27-29). Similar effects of physiotherapy in patients with vertigo were obtained in the present study. We found a reduction in the range of sways and improvements in visuomotor coordination, and thus also in balance control, and in a subjective feeling of the patient's well-being. An analysis of COP sways in the planes while keeping balance in the standing position confirms the stimulating influence of the exercise applied on balance control. In people with vertigo, conscious visual control while tracing the image of a moving COP might have caused vestibular nystagmus and in that way increased instability. Therefore, ICOP before therapy was negative and reflected the hip strategy, manifesting itself by an increased length of stabilogram in the frontal plane (L-R), differently with eyes open and closed. The applied conscious visual control of the body posture with self-correcting motions resulted in a change in the COP sways predominance from the hip strategy in the control test to the ankle strategy after the therapy. It should be assumed that repeated visual stimulation (biofeedback) caused an increase of ICOP and a decrease of instability. Due to conscious, visual control of an image moving on a screen, information about the degree of balance disorders acquired in the interactive process became triggered compensatory mechanisms having to do with the plasticity of the nervous system (13, 14).

In summary, physiotherapy resulted in a decrease of the range of sways and an improvement of visuomotor coordination, which improved balance control in the standing position in patients with vertigo. Visual stimulation resulted in an increase of the center-of-foot pressure index in the forced standing position with biofeedback and in a decrease of instability. Change of the center-of-foot pressure index in the biofeedback condition reflects the change of predominance of sways from the hip strategy in the control test to the ankle strategy after therapy.

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#### REFERENCES

1. Jansson EE, Mansson ON, Hakansson A. Effects of specific rehabilitation for dizziness among patients in primary health care. A randomized controlled trial. *Clin Rehabil* 2004; 18: 558-565.
2. Prieto L, Santet R, Cobo E, Alonso J. A new measure for assessing the health-related quality of life of patients with vertigo, dizziness or imbalance: the VDI questionnaire. *Qual Life Res* 1999; 8: 131-139

3. Friedman SM, Munoz B, West SK, Rubin GS, Fred LP. Falls and fear of falling which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. *J Am Geriatr Soc* 2002; 50: 1329-1335.
4. Herman SJ, Blatt P, Schubert MC, Tusa RJ. Falls in patients with vestibular deficits. *Am J Otol* 2000; 21: 847-851.
5. Pothula VB, Chew F, Lesser THJ, Dharma AK. Falls and vestibular impairment. *Clin Otolaryngol* 2004; 29: 179-182.
6. Yardley L, Donovan-Hall M, Smith HE, Bronagh MW. Effectiveness of Primary Care-Based Vestibular Rehabilitation for Chronic Dizziness. *Ann Intern Med* 2004; 141, 8: 598-605.
7. Kanagalingam J, Hajioff D, Bennett S. Vertigo. *BMJ* 2005; 330: 523.
8. Swarz R, Longwell P. Treatment of vertigo. *Am Fam Physician* 2005; 71, 6: 1115-1122.
9. Hall CD, Schubert MC, Herman SJ. Prediction of fall risk reduction as measured by dynamic gait Index in individuals with unilateral vestibular hypofunction. *Otol Neurotol* 2004; 25: 746-751.
10. Grimby A, Rosenhall U. Health-related quality of life and dizziness in old age. *Gerontology* 1995; 41: 286-298.
11. Gamiz MJ, Lopez-Escamez JA. Health-related quality of life in patients over sixty years old with benign paroxysmal positional vertigo. *Gerontology* 2004; 50: 82-86.
12. Enloe LJ, Shields RK. Evaluation of health-related quality of life in individuals with vestibular disease using disease-specific and general outcome measures. *Phys Ther* 1997; 77: 890-903.
13. Brandt T. Management of vestibular disorders. *J Neurol* 2000; 247: 491-499.
14. Herdman SJ. Vestibular rehabilitation. Philadelphia, FA Davis, 1999.
15. Hahn A, Sejna I, Stolbova K, Cocek A. Visio-vestibular biofeedback in patients with peripheral vestibular disorders. *Acta Otolaryngol* 2001; 545: 88-91.
16. Kammerlind ASC, Hakansson JK, Skogsberg MC. Effects of balance training in elderly people with nonperipheral vertigo and unsteadiness. *Clin Rehabil* 2001; 15: 463-470.
17. Konnur MK. Vertigo and vestibular rehabilitation. *J Postgrad Med* 2000; 46: 222-223.
18. Winter DA. Human balance and postural control during standing and walking. *Gait Posture* 1995; 3: 193-214.
19. Horak FB, Moore SP. The effect of prior leaning on human postural respondents. *Gait Posture* 1993; 1: 203-323.
20. Fitzgerald JE, Murray A, Elliott C, Birchall JP. Comparison of body sway analysis techniques. Assessment with subjects standing on a stable surface. *Acta Otolaryngol* 1994; 114: 115-119.
21. Danis CG, Krebs DE, Gill-Body KM, Sahrman S. Relationship between standing posture and stability. *Phys Ther* 1998; 78: 502-517.
22. Hudson CC, Krebs DE. Frontal plane dynamic stability and coordination in subjects with cerebellar degeneration. *Exp Brain Res* 2000; 132: 103-113.
23. Gauchard GC, Lascombes P, Kuhnast M, Perrin PP. Influence of different types of progressive idiopathic scoliosis on static and dynamic postural control. *Spine* 2001; 26: 1052-1058.
24. Kuczynski M, Ostrowska B. Understanding falls in osteoporosis: The viscoelastic modeling perspective. *Gait Posture* 2006; 23: 51-58.
25. Kuczynski M. Model lepko-sprężysty w badaniu stabilności postawy człowieka. Studia i Monografie. Wydawnictwo AWF, Wrocław, 2003; 7-15.
26. Winter DA. Human balance and posture control during standing and walking. *Gait Posture* 1995, 3: 193-214.
27. Bronstain AM. Suppression of visually evoked postural responses. *Exp Brain Res* 1986; 63: 655-658.
28. Hafström A, Fransson PA, Karlberg M, Ledin T, Magnusson M. Visual influence on postural control, with and without visual motion feedback. *Acta Otolaryngol* 2002; 122: 392-397.

29. Beidel DC, Horak FB. Behavior therapy for vestibular rehabilitation. *J Anxiety Disord* 2001; 15: 121-30.

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