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# PROVIDING BALANCE IN VERTICAL POSITION AFTER ISCHEMIC STROKE

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**Abstract**

Ischemic changes of the function of balance are characterized by an increase in the projected area of the center and the center of pressure displacement speed. Changes in peripheral blood flow to maintain balance affects mainly the frontal plane. Changing the regulation of vascular tone in the chain of peripheral blood flow affects the performance of dynamic balance, resulting in a reduction of the integral index of the balance function.
The brain ischemic death in Russia occupies the third position. As a result, the rehabilitation period after an ischemic stroke can disrupt the social and economic well-being of patients and their close relatives.
One of the main consequences of stroke are violations of limb mobility (paresis, paralysis). Their degree can be reduced with the help of rehabilitation measures intended to revive the motor function of paralyzed limbs and to train a patient to remain firm upright. A stabilographic rehabilitation training apparatus with biofeedback represents one of the variants of the posture training. Stabilization rehabilitation simulator with biofeedback is one of the options for training the posture. This exercise in a playful way helps the patient improve balance performance and durability of the vertical position. The method of rehabilitation significantly improved the clinical and stabilographic parameters of the patients' balance and elasticity functions in comparison with patients whose programs did not include this method.



**Keywords:** Coordination; balance; aging; disturbed cerebral circulation; ischemia.

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## 1. Introduction

A big health problem in Russia is the death rate from ischemic stroke. Mortality from ischemic stroke in Russia is in third place, except for only cancer and myocardial infarction. In addition, the disability rate in the first year after an ischemic attack is 80-85%. All this leads to a decrease in the patient’s as well as his / her family’s social well-being.

One of the major consequences of the stroke is impairment of the static and locomotor functions causing paralysis and paresis, gait disturbance. The degree of their impairment can be reduced by means of rehabilitation measures aimed at restoring mobility in the paralyzed limbs and training to retain a stable vertical position. One of the measures is to use the pose training simulators for stabilographic rehabilitation with biofeedback (BFB). This training conducted in the form of a game allows patients to improve the balance of performance and stability of the vertical strut (Bredikhina, & Baranova, 2016).

The most important condition for an active life of a person is the ability to maintain a balance in an upright position. For this, effective system of fine postural control of the body was developed in the process of phylogeny (the system of postural control aimed at maintaining the balance of the body in any way).

The postural control involves two components: postural stability and postural orientation. Postural stability means the ability to maintain a vertical position, which is related to the ability to maintain a center of body pressure within the support zone. Postural orientation is explained as the interaction between individual structures of the body, between the body and the surrounding space.

In addition, the system performance depends, firstly, on the postural control, and secondly, on the state of the musculoskeletal system and the condition of the nervous system. The stability of the vertical posture in greater level expression is expressed degree of freedom of movement in the joints, the strength and stability of the spinal column, as well as its elasticity and flexibility.

The postural stability personal control and balance has a high degree of reliability and durability, but for different ages are characterized by certain features of the functioning of this system. Thus, it is believed that healthy postural stability does not undergo great changes for healthy people aged 17 to 54 years, and children under the age of 10 years, and all people in the elderly group over the age of 60 are experiencing problems with space stability. that the age-related changes in the postural balance and postural stabilization functions occur independently of the processes associated with the aging rate.

In the International Classification of Diseases, falls comprise 19 points, which is a lot; 11 of them are falls from one’s own height. No wonder, a fall is classified as external causes of mortality and morbidity. According to the same report of the World Health Organization, 30 - 50% of people over 65 fall at least once a year. 10-15% of them end with severe injuries, 5% with hip fractures. However, 10-15% of

Aging is manifested by a decrease in the sensitivity of sensory systems and the functions of the bone and muscular apparatus, causing a decrease in the coordination among people in the middle and old age group. The development of postural instability as the consequence of such kind of falls for people at the age of 65 and over is a serious problem for people's health and social workers in many countries. For example, in the USA, it has been estimated that among all medical expenditures on people aged 65 and older, 6% fall on the recovery of the consequences of falls, and 13% of all deaths in this age group are a consequence of falls.

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Usually, the problem of falling is typical for the elderly at the age of 65 years and older, and even one fall in this age group may cause a decrease in the function of postural stability and may increase the risk of further falls (Baranova, & Kapilevich, 2015).

It is often believed that women aged 65 and over are more likely to fall than men of the same age; however, as experience shows, men are more likely than women to experience a drop, due to which the death occurs.

Nowadays, there is a problem of the earlier weakening of postural balance. Actually, as early as at the age of 40, there is some weakening of the function of postural stability, and there is rapid deterioration of this function in the people over 60 years old. In addition, the results of the study confirm that they are responsible for 5.3% of all hospitalizations and 90% of hip fractures.

The World Health Organization determines environmental risk factors, which, of course, is important for our country. They include an inconvenient layout of the house and yard; slippery, icy stairs; wet floor; poor lighting (Davletjarova, & Kapilevich, 2016).

Social risk factors include low income, social isolation of older people, lack of access to health care and prevention, unequipped apartments in a special way.

Biological factors are age and gender. The older the patients are, the more often they fall. Women fall oftener than men do. However, in men are more likely to die from these falls. There are a number of diseases that at any age, of course, increase the risk of falls.

There are important behavioral risk factors. Acts of falling, for whatever reason, can lead to severe maladjustment of patients in everyday life. Such falls are accompanied by severe injuries, including broken bones approximately in 1 per 10 cases. The risk of fractures due to falls is very high in patients with impaired movement (ataxia, paresis) after a stroke.

In addition, the significant role played by the center of balance shift in the age-related changes in posture. Wearing individually calculated loads in specialized backpacks will not only rectify older women's posture, owing to which they can get rid of back pain and improve their gait and balance, but also, as a result, will radically improve their way of life.

Usually the problem of falling is typical for the elderly people aged over 65, and even one fall at this age may bear evidence of a decrease of the function of postural stability and increase of the risk of further falls (Davletjyarova, & Korshunov, 2015).

A large number of studies are devoted to the study of the level of postural stability, focusing on the calendar age, however, there are very few known publications which consider the state of postural balance depending on indicators of the biological age of a human. It should be borne in mind that the calendar age is not always a correct reflection of the degree of age-related changes in physiological functions, i.e. Biological age.

The proper functioning of the postural control system is the main condition for the active lifestyle and social well-being of the elderly. Age-related changes in the postural stability of the system have become increasingly important, not only for medical, but social area. A low postural stability function is the main cause of falls and injuries of the elderly.

In recent years, the problem of falls of elderly people provoke growing medical, scientific and social research. Primarily, this is due to an augmentation of the calendar age, but, first of all, due to the biological age of the population in Russia (Azulay, & Vacherot, 2010)

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Functional diagnostics of the level of postural stability in the elderly population will allow one to identify the physiological differences between aging and pathology, determine what is causing the malfunction of the postural control system, and, consequently, an increase of the risk of falls. In recent years, in the field of age physiology and gerontology, greater attention is paid to the definition of biological age and the rate of aging, as well as their relationship with the functions of various systems of the old man's body.

Today, a new, high-quality way to diagnose the state of the human postural control system is actively introduced. The method is based on the analysis of stabilograms by the rate of the common center-of-mass (GCM) motion and called as a balance function indicator (EFI). The index of EFI is considered as an integral expression of the efficiency of the postural control system and enables researchers to introduce the elements of standardization in the posturology.

It largely determines the objective of this study.

The objective of the study is to evaluate the possibility of using stabilographic rehabilitation simulators with biofeedback (BFB) to improve the stability of the vertical posture of ischemic patients.

The object of the study is to examine 54 people aged from 54 to 65 who have suffered from ischemic stroke in the vertebral basilar basin and were undergoing treatment in Tomsk Research Institute of balneotherapeutics and physical therapy. Patients were separated into two groups. The stabilographic rehabilitation training apparatus with biofeedback was added to a course of treatment of the first group including 22 people (experimental group). The control group of 22 people received standard rehabilitation treatment (second group).

The balance indicators were estimated using the Romberg test. The purpose of the test is to assess the loss of stability with some decrease in concentration at the moment of distraction to perform parallel thought operations. The two probes were conducted with participation of patients: with open and closed eyes. The probes were carried out in sequence, one after another. In the test with open eyes, in order to divert the attention of the subject, the stimulation in the form of alternating circles of different colors was used. In so doing, it was necessary to count the number of white circles. In the test with closed eyes, for the same purpose, the stimulation in the form of sound signals, the number of which must be counted, was used. As a result, we examined the difference between the indices of both probes in quantitative terms: the ratio of indicators when the patients participated with their eyes closed to the indicators when patients participated with their eyes open. The study was performed using a computer stabilographic analyzer “Stabilan -1”.

Evaluation of the peripheral blood flow was performed by compression of the brachial artery with the pneumatic cuff. At the end of the three-minute compression, the vessel diameter was measured by an ultrasonic scanner “Vivid60”. After decompression using an ultrasound Doppler "ANGIODIN - PC", the blood flow rate was measured in the brachial artery.

## 2. Methods

Before and after the course of treatment, all the patients were tested by means of a computer stabiloanalyzer “Stabilan-01-2” with biofeedback (produced in Russia by ZAO OKB RITM) in order to evaluate the balance function. Evaluation of the peripheral blood flow was performed by compression of the brachial artery with the pneumatic cuff; at the end of the three-minute compression, the vessel diameter was measured by the ultrasonic scanner "Vivid60". After decompression using the ultrasound Doppler "ANGIODIN – PC", the blood flow rate was measured in the brachial artery.

The course of treatment lasted 21 days. During 15 days, the standard course of treatment of the first-group patients was additionally complemented by a 20-minute training on stabilografphic rehabilitation training devices with biofeedback. Two training programs were employed: "Blocks Training" and "Balls Training". Using these techniques, aged people learned to control their centre of gravity which helped them to recuperate the feeling of steadiness.

During the training with BFB, the patient got onto a special platform. Fluctuations in the patient's center of pressure were displayed on the screen in the form of a cross; the screen was located at patient's eye level. The first task consisted in the shifting of the patient's center of pressure, keeping the feet flat on the platform (without raising), to the ball, superimposing the cross on the ball (which reflects the center of pressure), and moving the resulted shape to the flashing cart at the bottom of the screen. In the second task, the patient's pressure center was reflected in the form of a cube on the screen. Using these cubes, it was required to build a horizontal line. It was again forbidden to raise the feet from the platform (keeping them flat on the platform). During the training, it was always required to safeguard the patient against falling. Classes were held in the morning.

Data analysis was performed using software Statistic 6.0 for Windows firms' Stat soft. For determination of the nature of the distribution of the data, the Kolmogorov-Smirnov test was used. The hypothesis about the belonging of the compared independent samples to the same general population or populations with the same parameters was checked by a rank Mann-Whitney U-criterion. The degree of the interrelation was assessed using Spearman's correlation ratio.

## 3. Results and discussion

No visible statistic differences between two groups were found during the stabilographic Romberg's test before the treatment. The patients of both groups were generally diagnosed with the centre of gravity (COD) deviation in sagittal and frontal planes, with accelerated COD displacement and the damaged balance function (table 1).

After the treatment, the rates of COD dispersion over the frontal plane with eyes closed and open reduced reliably in the experimental group ($p<0.05$); in the control group, however, it was reduced only when the test was carried out with eyes closed ($p<0.05$, table 1). Moreover, Romberg's test with eyes closed showed that this rate was significantly lower in the experimental group than it was in the second group ($p<0.05$, table 1).

In the control group, the sagittal plane rate data after the treatment differed from the results of Romberg's test with open eyes before treatment ($p<0.05$). In the experimental group, the same rate (in both variants of Romberg's test) was also different from the ones before treatment, but the results of the groups were not the same ($p<0.05$, table 1).

The average dispersion of the experimental group patients was regressing while carrying out both types of Romberg's test ($p<0.05$); at the same time, in the control group, it was reducing only when the test was carried out with eyes closed ($p<0.05$, table 1). Romberg's test results with eyes open were the lowest in experimental group ($p<0.05$, table 1).

Romberg's test with open eyes showed that in the experimental group, the average displacement rate of the centre of pressure reduced noticeably ($p<0.05$), whereas in the control group the same effect was proved by Romberg's test with eyes closed ($p<0.05$, table 1).

The rate of change of a force plate's surface diagram reduced only in the experimental group ($p<0.05$, table 1).

The balance function was improving in both cases of Romberg's test in the first group ($p<0.05$, table 1). In the second group, this favorable effect was noticed only in case of Romberg's test with open eyes ($p<0.05$, table 1).

The average line rate was lower only in the experimental group after the treatment ($p<0.05$, table 1).

The Romberg index reduced in both groups, but in the experimental group, this reduction was more substantial ($p<0.05$, table 1).

When implementing rehabilitation programs during the course of treatment, the patients of the experimental and control groups scored from 3 to 5 points (Table 2). After 15 days of treatment, there was an improvement of this indicator to $11.9 \pm 0.9$ in the experimental group, and to $6.7 \pm 0.7$ — in the control group ($p < 0.05$, Table 2). The number of dialed strings after treatment increased in both groups. But more significant results were observed in patients of the experimental group (table 2).

The capturing time interval is reduced by half in patients of the experimental group; there is no reliable changes in the control group ($p < 0.05$, Table 2). The interval time of stacking balls and cubes after treatment has changed significantly in both groups ($p > 0.05$, Table 2).

Indicators of the capture rate increased by 85% in the experimental group, and by 43% — in the control group ($p > 0.05$, Table 2).

After treatment, the velocity interval of stacking increased by 283% in the first group and slightly increased by 190% in the control group ($p < 0.05$, Table 2).

The most noticeable changes were observed among the patients of the experimental group who trained on rehabilitation simulators equipped with biofeedback in addition to the basic course of treatment. After the course of treatment, it became easier for these patients to manipulate their pressure center and to keep stability in an uncomfortable position.

According to the responses of the patients from the experimental group, they felt more or less steady standing on both feet and could recuperate practically full sensitivity in lower limbs.

Thus, we can trace the improvement in patients' states after the treatment which results in development of the static balance sense – optimized functioning of the vestibular analyzer. The balance sense becomes more independent from the visual analyzer. We identified the increased dispersion and surface of COD displacement as well as adequate changes in the rate. In addition, we could trace the improvement of the balance function and the Romberg index. At the same time, it should be noted that the patients who besides the standard treatment exercised using stabilographic rehabilitation training devices with biofeedback achieved better results. In the course of the training, the patients learnt to control the position of the general pressure center of their body while training the balance function.

**Table 01.** Stabilographic figures demonstrating the results of Romberg's test before and after the treatment for patients suffering from ischemic stroke.

$X_{ave}$±m

| Performance figures | Experimental group | | | |
|---|---|---|---|---|
| | Before the treatment | | After the treatment | |
| | Open eyes | Closed eyes | Open eyes | Closed eyes |
| COD dispersion over frontal plane of, mm | 5.49± 0.09# | 8.92±0.95 # | 4.15±0.3 | 6.1±0.6* |
| COD dispersion over sagittal plane, mm | 7.33± 0.5# | 6.73±0.6 # | 4.6±0.5* | 4.2±0.3* |
| Average dispersion, mm | 6.4±0.7# | 7.66±0.6# | 4.5±0.5* | 5.6±0.4 |
| Average displacement rate of the centre of pressure, mm/sec | 15.3± 0.8# | 17.8±1.2 | 10.6±0.6* | 13.8±0.9 |
| Rate of change of a force plate's surface diagram, $mm^2$/sec | 17.5±1.5# | 35.3±2.7# | 12.2±0.9* | 22.3±1.4* |
| Balance function quality, % | 47.2±6.2# | 32.1±2.5# | 74.3±8.3* | 49.9±3.7* |
| Average line rate, mm/sec | 6.8±0.8# | 9.4±0.7# | 4.5±0.3* | 7.3±0.5 |
| Romberg index | 340±29# | | 245.5±20* | |

| Performance figures | Control group | | | |
|---|---|---|---|---|
| | Before the treatment | | After the treatment | |
| | Open eyes | Closed eyes | Open eyes | Closed eyes |
| COD dispersion over frontal plane of, mm | 5.61±0.7 | 8.75±0.6# | 4.21±0.3 | 6.37±0.7 |
| COD dispersion over sagittal plane, mm | 7.01±0.8# | 6.5±0.6 | 5.4±0.4 | 4.65±0.3 |
| Average dispersion, mm | 6.32±0.8 | 7.63±0.9# | 4.8±0.4 | 5.5±0.4 |
| Average displacement rate of the centre of pressure, mm/sec | 15.7±0.9 | 17.1±1.4# | 13.8±1.1 | 12.1±0.9 |
| Rate of change of a force plate's surface diagram, $mm^2$/sec | 17.2±1.4 | 32.9±2.1 | 14.9±0.9 | 25.7±2.3 |
| Balance function quality, % | 47.85±5# | 35.2±2.2 | 61.3±5.1 | 45.6±3.8 |
| Average line rate, mm/sec | 6.55±0.7 | 8.4±0.7 | 5.3±0.2 | 6.9±0.6 |
| Romberg index | 334.3±29# | | 285.7±16 | |

* – accuracy of differences relatively the control group, $p<0.05$;
# – accuracy of differences inside the group before and after the treatment, $p<0.05$.

**Table 2.** Stabilographic figures demonstrating the results of rehabilitation rehabilitation programs before and after the treatment for patients suffered from ischemic stroke.

$X_{ave}$±m

| Performance figures | Experimental group | |
|---|---|---|
| | Before the treatment | After the treatment |
| Points | 4.1±0.4 | 11.9±0.9* |
| Lines | 0.9±0.09 | 4.5±0.5 |
| Capture time interval, sec | 7.8±0.9 | 3.5±0.4* |
| Stacking time interval, sec | 14.2±0.9* | 7.3±0.9* |
| Time interval of capture rate, mm / sec | 48.2±3.2# | 89.3±8.3 |
| Time interval of stacking rate, mm / sec | 20.4±1.1*# | 78.3±7.4* |
| Performance figures | Control group | |
| | Before the treatment | After the treatment |
| Points | 3.95±0.8 | 6.7±0.7 |
| Lines | 0.95±0.09 | 2.4±0.5 |
| Capture time interval, sec | 7.3±0.8 | 5.7±0,6 |
| Stacking time interval, sec | 13,7±1.2 | 10.8±1.3 |
| Time interval of capture rate, mm / sec | 46.7±0.5 | 67.2±10 |
| Time interval of stacking rate, mm / sec | 19.9±0.9# | 58.6±6.3 |

* – accuracy of differences relatively the control group, p<0.05;
# – accuracy of differences inside the group before and after the treatment, p<0.05.

Measuring the pulse wave velocity of the patients in the experimental group in a sample with postocclusive reactive hyperemia showed (Table 3) some increase in the systolic blood flow velocity by 22.7 ± 1.8% (p <0.05), diastolic — by 43.2 ± 3.5% (p <0.05) and average — by 31.9 ± 3.1% (p <0.05). Pulse and resistive indices decreased by 61.4 ± 5.7% (p <0.05), and 30.1 ± 3.4% (p <0.05), respectively. During ultrasound examination, the compression of the brachial artery revealed luminal occlusion by 32.5 ± 4.1% (p <0.05%).

An increase in the area of the ellipse motion of the common center of gravity on account of not only the existence of neurophysiological but also anatomic prerequisites is typical for age-related changes of the stability of the balance function. In this case, obvious changes in the joints, loss of mobility and elasticity of muscles, reduced coordination and speed of movements are of particular importance.

Registration of the stabilogram with open and closed eyes allows one to evaluate the increasing influence of the visual analyzer for the elderly. If the eyes are closed, the balance in the vertical position is maintained only at the expense of proprioception.

**Table 3.** Indicators of Doppler velocimetry of brachial artery

$X_{ave}$± m

| Indicators | Before compression | After decompression | 1 min. after decompression | 2 min. after decompression |
|---|---|---|---|---|
| Systolic blood flow velocity, cm/s | 34.33±2.8 | 41.88±3.9* | 37.00±3.5 | 36.00±2.8 |
| Diastolic blood flow velocity, cm/s | 4.72±0.2 | 6.76±0.4* | 5.28±0.3 | 4.00±0.2 |
| The average flow velocity, cm/s | 11.70±1.1 | 15.60±1.2* | 12.56±0.9 | 10.67±1.3 |
| Pulse index | 2.71±0.1 | 1.06±0.1* | 2.66±1.3 | 3.14±0.2 |
| Resistive Index | 0.86±0.4 | 0.61±0.6* | 0.84±0.7 | 0.91±0.7 |

* - accuracy of differences of indicators in the group relatively the indicators before compression, p <0.05;

The average and systolic blood flow velocities have a positive relationship of the average strength with frontal displacement (0.32 and 0.35, respectively; $p < 0.05$) and with frontal dispersion (0.36 and 0.35, respectively; $p < 0.05$). Dynamic indicators - the area of the ellipse (0.33; $p < 0.05$), the rate of displacement of the gravity center (0.49, $p < 0.05$), the rate of the area change (0.36; $p < 0.05$) have a positive relationship of the average strength with narrowing of the lumen of blood vessels. On the other hand, narrowing of the lumen of blood vessels has a negative relationship with the FIU (-0.49; $p < 0.05$). Moreover, all these relationships were detected only with the eyes closed.

## 4. Conclusion

Transformation in the peripheral blood flow affect the ability to maintain the balance mainly in the frontal plane. This effect is partially offset by the visual analyzer. Changes in the regulation of vascular tone in a part of the peripheral blood flow affect the indicators of dynamic balance, resulting in some reduction of the integral indicator of the balance function quality.

The conducted research allowed one to evaluate the positive effect of using stabilographic rehabilitation training devices with biofeedback in order to improve upright posture stability of patients suffered from ischemic stroke. Patients obtained more stability on both feet and could recuperate practically full sensitivity in lower limbs. In the course of the training, the patients learnt to control the position of the general gravity center of their body while training the balance function. There was an ongoing increase in the degree of freedom of movement in the upper and lower extremities. The social and economic well-being of patients and their close relatives has improved considerably due to their improved psychological state. Thanks to rehabilitation actions aimed at enhancement of the motor function in paretic extremities and training the patients to keep an upright position, it became possible to decrease the disability rate during the first year after experiencing an ischemic attack.

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