

LITHUANIAN ACADEMY OF PHYSICAL EDUCATION

Vilma Juodžbalienė

**THE DEPENDENCE OF SIMPLE AND PSYCHOMOTOR
REACTION AND EQUILIBRIUM MAINTENANCE OF
ADOLESCENTS ON THE DEGREE OF VISUAL
IMPAIRMENT**

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Scientific supervisor

Prof. Dr. Habil. Kazimieras MUCKUS (Lithuanian Academy of Physical Education, biomedical sciences, biology – 01B).

Scientific adviser

Dr. Habil. Antanas KURAS (Kaunas University of Medicine, biomedical sciences, biology – 01B).

Doctoral dissertation will be defended at the Biology Sciences Council of the Lithuanian Academy of Physical Education:

Chairman

Prof. Dr. Habil. Albertas SKURVYDAS (Lithuanian Academy of Physical Education, biomedical sciences, biology – 01B).

Members

Assoc. Prof. Dr. Aleksandr BULATOV (Kaunas University of Medicine, biomedical sciences, biology – 01B).

Prof. Dr. Egidijus KĖVELAITIS (Kaunas University of Medicine, biomedical sciences, medicine – 07B).

Prof. Dr. Dainius Haroldas PAUŽA (Kaunas University of Medicine, biomedical sciences, biology – 01B).

Dr. Sonata TRUMBECKAITĖ (Kaunas University of Medicine, biomedical sciences, biology – 01B).

Opponents

Prof. Dr. Habil. Alyudas PAUNKSNIS (Kaunas University of Medicine, biomedical sciences, medicine – 07B).

Dr. Aivaras RATKEVIČIUS (Lithuanian Academy of Physical Education, biomedical sciences, biology – 01B).

The doctoral dissertation will be defended in the open session of the Biology Science Council of the Lithuanian Academy of Physical Education. The defense will take place on 16th of December, 2005 at 11 a.m. in auditorium 218.

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LIETUVOS KŪNO KULTŪROS AKADEMIJA

Vilma Juodžbalienė

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Mokslinis vadovas

Prof. habil. dr. Kazimieras MUCKUS

Lietuvos kūno kultūros akademija (biomedicinos mokslai, biologija – 01B).

Konsultantas

Habil. dr. Antanas KURAS

Kauno medicinos universitetas (biomedicinos mokslai, biologija – 01B).

Disertacija ginama Lietuvos kūno kultūros akademijos Biologijos mokslo krypties taryboje:

Pirmininkas

Prof. Habil. dr. Albertas SKURVYDAS

Lietuvos kūno kultūros akademija (biomedicinos mokslai, biologija – 01B).

Nariai

Doc. Dr. Aleksandr BULATOV

Kauno medicinos universitetas (biomedicinos mokslai, biologija – 01B).

Prof. Dr. Egidijus KĖVELAITIS

Kauno medicinos universitetas (biomedicinos mokslai, medicina – 07B).

Prof. Dr. Dainius Haroldas PAUŽA

Kauno medicinos universitetas (biomedicinos mokslai, biologija – 01B).

Dr. Sonata TRUMBECKAITĖ

Kauno medicinos universitetas (biomedicinos mokslai, biologija – 01B).

Oponentai

Prof. Habil. Dr. Alvydas PAUNKSNIS

Kauno medicinos universitetas (biomedicinos mokslai, medicina – 07B).

Dr. Aivaras RATKEVIČIUS

Lietuvos kūno kultūros akademija (biomedicinos mokslai, biologija – 01B).

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ABBREVIATIONS

CNS	–	central nervous system
B	–	investigative group of totally blind subjects
L	–	investigative group of legally blind subjects
S	–	control group of sighted subjects
E	–	equilibrium
SR	–	simple reaction
PMR	–	psychomotor reaction
COM	–	center of mass
COP	–	center of pressure
COG	–	center of gravity
Δx	–	COP displacement in sagittal axis (direction)
Δy	–	COP displacement in transversal axis (direction)
s	–	COP pathway length
$x_{0-0.7 \text{ Hz}}$	–	sway amplitude along the sagittal axis at frequency range of 0 – 0.7 Hz
$x_{0.7-1 \text{ Hz}}$	–	sway amplitude along the sagittal axis at frequency range of 0.7 – 1 Hz
$x_{1-2 \text{ Hz}}$	–	sway amplitude along the sagittal axis at frequency range of 1 – 2 Hz
$y_{0-0.7 \text{ Hz}}$	–	sway amplitude along the transversal axis at frequency range of 0 – 0.7 Hz
$y_{0.7-1 \text{ Hz}}$	–	sway amplitude along the transversal axis at frequency range of 0.7 – 1 Hz
$y_{1-2 \text{ Hz}}$	–	sway amplitude along the transversal axis at frequency range of 1 – 2 Hz
t	–	duration of SR
t_{lat}	–	the latent duration of PMR
t_{mov}	–	the movement duration of PMR
t_{off}	–	the total duration of PMR

I. INTRODUCTION

The quality of equilibrium maintenance, orientation in space and accuracy and coordination of movements while standing or walking comes to be particularly significant during the present age of technology progress. To participate in different activities and under various conditions, one needs to manage right body posture and movement control. The application possibility of widely developed methods for researching on equilibrium and human response to various signals allows the researchers to discover new properties and to form a new attitude towards proprioception, vestibular apparatus, vision and nerve-muscle system integral activity.

Equilibrium helps to maintain a vertical posture and not to fall when in standing position or during performance of complex movement tasks. Scientific research indicates that equilibrium stability is based on the control of a body mass centre (El – Kashlan et al., 1998). To maintain the vertical posture, integration of information on vision, vestibular labyrinth, proprioception and sole mechanoreceptors is needed (Jeka et al., 1998; Yasuda et al., 1999). The equilibrium control system includes plenty of processes that could be divided into two different, yet related, groups: the system stabilizing the sight and the one stabilizing the body posture (Nashner, 2001). The sight stabilization depends on interdependency of information on the sight direction from the vestibular apparatus and from the vision analyzer, and depends on oculomotorics and functional capabilities of central nervous system (CNS) as well. Equilibrium control is determined by interdependency of information on body and its segment orientation from vision analyser, inner ear vestibular apparatus and proprioception senses caused by the contact with the support, and it is determined by both motor response, which controls limb and waist muscle activity, and CNS function.

To control effectively activities, body segment position and movement in space, a capability to respond to the surrounding stimuli and initiate a reflex or conscious reaction to them is particularly significant. The duration of the psychomotor reaction is especially important, it characterizes the reaction to a complex signal and not only reflects the latent and movement durations but allows estimation of the duration of situation perception as well.

Optimal interaction between vision and other somatosensory systems guaranties the control of human body segment stability and change in position. Plenty of authors maintain that lack of visual information causes changes in equilibrium, regulation of body segment position and in response to surrounding stimuli (Nougier, 1998; Bronstein and Guerraz, 1999; Kristinsdottir et al., 2001). While evaluating change in response to the different light and sound stimuli and its dependence on certain factors, most frequently are considered subject age, sex, signal intensity, its kind, mastering, CNS condition and position of visual signal

projection in the retina (Jevas and Yan, 2001; Redfern et al., 2002; Ando et al., 2002; Kosinski, 2004).

There is no doubt about the importance of visual information influence on equilibrium control. Numerous research studies have been created to find out the visual information influence on body position or on activity of other sensorymotor system (Collins and De Luca, 1995; Ishida et al., 1997; Jeka et al., 1998; Bardy et al., 1999; Bronstein and Guerraz, 1999; Ferdjallah et al., 1999; Golomer et al., 1999; Guerraz et al., 2000; Guerraz et al., 2001; Kristinsdottir et al., 2001; Hafstrom et al., 2002; Brooke-Wavell et al., 2002). In all literature sources analysed, the scientific problems have been researched considering only visual information, or having it eliminated; equilibrium and reaction dependence on vision on the whole has been researched as well, still it has not been clear what influence on the a.m. change vision and the degree of visual impairment have and, also, the activity of other sensory systems when vision is excluded from equilibrium and reaction processes.

Due to the technology progress the survival of aborted newborns and that of children who have experienced eye traumas appear to be possible. In Lithuania the survival of newborns of extremely small body weight (<1000 g) has increased from 12 % in 1993 to ~53 % in 2002, that of newborns of very small body weight (1000–1500 g) – from 48.3 % in 1993 to 88 % in 2002. These newborns are in danger of somatic and development disorders, which may cause disability. 40.21 % of newborns of very small body weight suffer from aborted newborn retinopathy that causes visual acuity disorders (Jurgaitienė, 2004).

The blind by nature possess fewer possibilities to develop their psychomotor functions. It has been confirmed that blind children start doing active purposive movements only then, when sound commands are perceived, which activate their movement (Fraiberg, 1977; Ribadi et al., 1987). This fact hinders the psychomotor development of visually impaired children. As is known, the static equilibrium presents itself as one of the substantial elements for the smooth motor development (Geuze, 2003). Thus, it is extremely important to clear the dependence of such significant movement components as equilibrium and reaction on vision disorders.

The novelty of the research. These days numerous researchers are interested in problems of handicapped people concerning psychomotor development, education and socialization. Most frequently, the research is carried out in connection with mentally and physically handicapped. We have found only few scientific articles in Lithuania and all over the world on equilibrium and psychomotor reaction particularities of people with vision disorders (Fraiberg, 1977; Bernard, 1979; Ribadi et al., 1987; Burton, 1992; Guerraz et al., 2000; Puišienė, 2000; Lee and Scudds, 2003; Pietrini et al., 2004). Both the equilibrium and simple reaction have been estimated employing clinical and Eurofit testing. In no case the equilibrium and psychomotor reaction values have been surveyed applying instrumental laboratory methods, and no quantitative estimation has been performed for such research results.

So far it has not been established when the control of equilibrium and response to the surrounding stimuli is more effective: in case of visual impairment or in case of total blindness. It has not been cleared whether there is a connection between the degree of visual impairment and equilibrium and psychomotor reaction values.

In this study we are aiming at gaining of new results on visual information influence on equilibrium and psychomotor reaction values on the whole, and at receiving information on sensorymotor particularities of people with vision disorders. During the research, the possibilities of application of biomechanical instrumental investigation methods have been in focus when they are being employed for surveying of equilibrium and psychomotor reaction values of handicapped people. We presume that the research results will be useful for the professionals associated with education of people with vision disorders, their social rehabilitation, with elite sports for the blind and legally blind, and for physiologists with the interest in the role that the vision sensory system plays during the processes of equilibrium and simple and psychomotor reactions.

The objective: to carry out the research on the influence of the degree of visual impairment on equilibrium and simple and psychomotor reactions, and to establish the possible manifestation of compensatory reactions of vestibular and proprioception sensory systems when vision disorders are being faced.

Tasks:

1. To establish adolescents' particularities of static equilibrium values when the adolescents are sighted or legally blind, and when the vision is present but visual information is eliminated, and to establish static equilibrium particularities of those who are totally blind.
2. To establish adolescents' values of simple and psychomotor reactions to the light and sound when they are sighted or legally blind, and, as well, the values of simple and psychomotor reactions to the sound of those who are totally blind.
3. To make a comparison between equilibrium, simple and psychomotor reaction values of adolescents who are sighted, legally blind and totally blind.
4. To establish the level of interconnection between the degree of visual impairment and equilibrium and simple and psychomotor reactions, and to investigate the manifestation of compensatory reactions of vestibular and proprioception sensory systems.

Hypothesis:

The values of equilibrium and simple and psychomotor reactions depend on the degree of visual impairment, and visual information determines higher values of equilibrium and simple and psychomotor reactions; with vision disorders being evident, the compensatory reactions of vestibular and proprioception sensory systems emerge.

II. THE RESEARCH METHODOLOGY AND ORGANIZATION

2.1. Subjects

The research has been performed accordingly to The Convention of 19th of November 1996 for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine (Convention on Human Rights and Biomedicine) (Rodgers and de Bousingen, 2001). The permit to perform the research has been issued by Lithuanian Bioethics Committee, Kaunas branch (Protocol Nr. 51).

The subjects that have expressed their willingness to take part in the study have been selected accordingly to the following criteria:

- 1) the degree of visual impairment,
- 2) CNS functional status,
- 3) secondary disorders of health,
- 4) physical state,
- 5) age.

Prior to the agreement on the participation in the experiment, the subjects and their parents have familiarized themselves with a form, providing personal information, and have signed the agreement form for an informed person.

45 subjects voluntarily participated in the study. To investigate the influence of the degree of visual impairment on equilibrium and simple and psychomotor reactions, the sighted subjects, legally blind and totally blind subjects have been selected. The investigative groups have been formed according to the purposive principle of investigative group organizing (Kardelis, 2002).

The subjects have been divided into groups considering their visual impairment degree (Gudonis, 1998). A visual impairment degree is established with regard to the visual acuity and visual field state (Table 1).

Table 1. Subjects characterization.

Group	Visual impairment degree	Subjects	Age (years)	Gender
B (totally blind)	Total blindness Visual acuity – 0, no visual field.	n = 12	13 ± 2	Six girls, six boys.
L (legally blind)	Legal blindness Visual acuity – 0.01 – 0.04, visual field – to 10°.	n = 13	13 ± 2	Six girls, seven boys.
S (control) (sighted)	Normal vision. Visual acuity – 0,8 and more, visual field – more than 120°.	n = 20	12 ± 0,7	Ten girls, ten boys.

The wearing of glasses does not change visual acuity of subjects from groups S, L and B.

As the function of the vision system comes to be multiple, i.e. it includes exploration of the environment, reflection of the objects, posture control, gaining of information, it cannot be determined only by the visual acuity data. The vision system consists of sensory (visual acuity), cognitive (sensory information being processed by CNS) and motor elements (eyeball movements) (Niessen and Montezzer, 2002). It is known, that with disorders that occur during activity of these elements, the function of vision changes itself, thus, the anamnesis of disorders of CNS development and cognitive processes has been verified.

The subjects with vision disorders have not had secondary disorders of health. No one among the subjects has been going in for sports regularly. The sighted and legally blind subjects have not had any experience in movements with blindfolded eyes.

The subjects' age vary from 11 to 15 years. Purposely younger adolescents had not been included into the study, as scientific research has proved that children aged 7 – 8 (Nougier, 1998) or aged 8 – 10 (Baumberger et al., 2004) experience a critical stage of development of sensorymotor processes of equilibrium control (especially of vestibular apparatus, Cherng et al., 2001). Some investigators maintain that equilibrium values of subjects aged 7 – 18 do not depend on age, height and body mass (Lebiedowska, Syszevska, 2000).

Having compiled the anamnesis on the vision condition of the subjects, we have found out that the subjects from group B have been diagnosed with congenital retinopathy or optic nerve atrophy. The subjects from group L have been diagnosed with optic nerve atrophy, choriorethinitis or corneal dystrophy. In cases of optic nerve atrophy, corneal dystrophy and choriorethinitis, both the peripheral and central vision worsens (Daktaravičienė et al., 1992).

2.2. Methods

2.2.1. *The equilibrium testing*

Static posturography. To investigate the connection between the equilibrium and the degree of visual impairment, a laboratory experiment has been organized. B, L and S groups have participated in the experiment.

A static posturography (or stabilography) method has been selected from numerous others for the equilibrium testing (Goebel and Paige, 1990; Baloh et al., 1998; Duarte et al., 2000; Stabilography, 2000; Duarte and Zatsiorsky, 2002). The change in an organism while in a standing position, can be recorded employing the methods of electromyography, vein pressure measurement, heart rate calculations, subjective assessment of comfort, observation of body segment kinematics, change in foot size and skin temperature measurement, still only kinematic analysis of a standing task, and posturography as well, allow the researchers to perform quantitative analysis (Duarte and Zatsiorsky, 1999).

Apparatus. A force plate and computerized equipment for analysis of the signals is applied for posturography. The force plate records the oscillations of pressure centre (COP) and gravity centre (COG) along the sagittal (x) and transversal (y) axes. Change in COP position reflects change in the ground reaction force, in the ankle torque and COP pathway (statokineziogram), and it is a graphical representation of varying with regard to time forces, which occur during the balance maintenance (Ishizaki, 2002).

A complex of dynamometric devices “Modul A”, which includes a force plate of serial manufacturing “MA-1”, a transducer to transform three projections of the force vector and computerized equipment for the analysis of signals being recorded was used in the study (Fig.1). The purpose of the complex comes to be registration and analysis of the static and dynamic values during standing and movement.

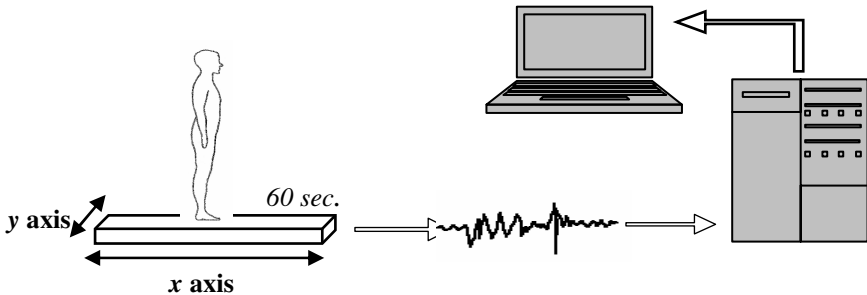


Fig.1. The complex of dynamometric devices. Axis y – oscillations of the COP in the transversal direction, axis x – oscillations of the COP in the sagittal direction, 60 sec. – recording duration of the posturogram.

Experiment. To ensure the confidentiality of the subject data, a code has been attached to every subject. The subjects have been informed repeatedly on the experiment course. The curves representing change in COP coordinates have been started to be registered since the moment when the subject in bare feet stands on the force plate in the position required. Posturogram registration in every position of standing lasted 60 s.

Posturograms have been registered when standing in different postures (Table 2), and the influence of vision on the equilibrium has been investigated covering the eyes of the subjects by opaque glasses and in this way eliminating visual information (blindfolded).

While registering the coordinates of COP position, we obtain the pathway of COP on the transversal plane.

Table 2. The conditions for equilibrium testing with regard to the support area and visual information.

Groups	Postures	Visual information
S, L, B	1 – side-by-side stance, hands by side	Eyes opened
	2 – side-by-side stance, hands by side	Blindfolded
	3 – side-by-side stance, hands reached forward	Eyes opened
	4 – side-by-side stance, hands reached forward	Blindfolded
	5 – tandem stance, hands by side	Eyes opened
	6 – tandem stance, hands by side	Blindfolded
	7 – tandem stance, hands reached aside	Eyes opened
	8 – tandem stance, hands reached aside	Blindfolded

The spectrogram of posturogram being registered is not uniform, thus, to evaluate it, several ranges of oscillation frequency have been chosen: 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz.

As the signal can be expressed by sinusoidal waves of certain length and frequency, a Furrier transformation has been employed for the change data of 60 sec. duration in COP coordinates for every subject. The signal of COP oscillation has been expressed in digitals. Discretization of the COP oscillation signal being registered has been 10 ms.

The analysis of the posturogram has been carried out evaluating the dependent variables:

1. COP displacement along the sagittal axis – Δx (mm),
2. COP displacement along the transversal axis – Δy (mm),
3. COP pathway length – s (mm),
4. sway amplitude along the sagittal axis at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz – x 0 – 0.7 Hz (mm), x 0.7 – 1 Hz (mm), x 1 – 2 Hz (mm),
5. sway amplitude along the transversal axis at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz – y 0 – 0.7 Hz (mm), y 0.7 – 1 Hz (mm), y 1 – 2 Hz (mm).

2.2.2. The simple reaction testing

The measurement of the simple reaction duration. The simple reaction (SR) presents itself as a response of an organism to the familiar signal (Stonkus, 1996). In the scientific research studies a simple reaction is presented as a reaction of an organism when only one signal exists and so does only one response (Kosinski, 2004). To investigate a simple reaction, various equipment is applied that registers the time interval between the beginning of the signal and the response to it: a chronometer (Delignieres and Brisswalter, 1996), computerized equipment (Delignieres and Brisswalter, 1996; Scott et al., 2002) etc.

Apparatus. To investigate a simple reaction, we have employed an electromyoreflexometer, which consists of the equipment emitting light or sound signals, a response device and a unit for the data registration. The purpose of this device is to register the values of motor reaction, the values of verbal reaction and the components of myoelectric reactions with regard to time. The electromyoreflexometer registers the latent duration of the simple reaction, the length of verbal, motor and myoelectric reactions and the difference in duration values of the motor and myoelectric reactions.

Experiment. The testing has been conducted during two parts when a simple reaction to the light has been investigated and the one of response to the sound. Analogically to the equilibrium testing, every subject has been with a code attached. The subject has been informed repeatedly on the experiment course. The testing has been conducted in quiet room, in a dim premise. The teacher for low vision acquainted the partially sighted subjects with the device and the array of buttons there. The subject and the researcher were sitting at different desks. The task for the subject presented itself as an interrupting of the light signal (for groups L and S) or the sound one (for groups B, L and S) by pressing the button as promptly as possible (Fig. 2). During the testing every subject performed 10 trials for PR to the sound signal and 10 trials for SR to the light signal. The break between the responses to the light and to the sound continued for 1 min.

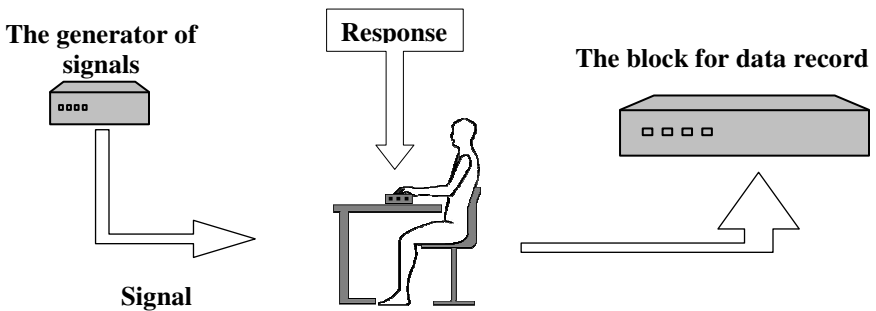


Fig. 2. The scheme for the simple reaction testing.

The results of the simple reaction testing have been grouped considering the investigative group and the kind of signal. The analysis has been carried out evaluating the dependent variable t (s).

2.2.3. *The psychomotor reaction testing*

The measurement of components of psychomotor reaction. The psychomotor reaction of a human being (PMR) is a reaction, during which the response should match a certain signal (Kosinski, 2004). PMR includes several components: duration of the reaction and the sensorymotor accuracy (Stonkus, 1996).

The standardized methods for PMR investigation exist: the subject must switch off from the certain starting position one of the light sources that has been lit at random (Stonkus, 1996). During the experiment, the time period is being measured between the switching on the light and switching it off. The data, obtained during PMR testing, are used to evaluate the attention, the speed of information processing and the sensorymotor response.

Apparatus. The PMR testing system consists of a force plate (the analogous one was used during the equilibrium testing), of six white light and sound sensors that have been arranged around the plate in half arc position (in intervals of 36° , i.e. I and VI sensors at 0° , II and V sensors at 36° , III and IV sensors at 72°) the equipment emitting the sound and light signals and computerized equipment for the registration and analysis of the force plate and sensor signals. The PMR testing system has been created at Lithuanian Academy of Physical Education, department of Biomechanics, Informatics and Engineering (Muckus et al., 1999; Muckus, Kriščiukaitis, 1999).

Experiment. The testing has been conducted during two parts, during the first part a PMR to the light has been investigated and during the other part a PMR to the sound has been tested. Analogically to the equilibrium and SR testings, every subject has been with a code attached. The subject has been informed repeatedly on the testing course. The testing has been conducted in quiet room, in a dim laboratory. The teacher for low vision acquainted the partially sighted subjects with the testing devices and the array of sensors. All subjects from group L maintained that they could see the light and sound sensors, i.e. the sensors occurred in their visual field.

Every subject had to stand on the centre of the force plate. During the first part of the experiment the subjects had to interrupt the light signal as promptly as possible (L, S), and during the second part – to interrupt the sound signal (B, L, S). The light or sound signal has been interrupted by touching a sensor. The order of sensor switching on has been random. Every sensor in succession has been switched on in 2 – 5 sec. after the previous sensor has been switched off. Every

subject performed 10 trials during the testing of PMR to the light and 10 trials during the testing of PMR to the sound.

The break between the responses to the light and to the sound continued for 1 min.

As the subjects were standing on the force plate, during every ballistic movement they caused change in the ground reaction force. This change and switching off the light and sound signals have been registered automatically by the computerized equipment. On the curve registered we have distinguished the latent PMR duration (t_{lat}), the movement duration (t_{mov}) and the total PMR duration (t_{off}).

t_{lat} , which reflects the speed of signal identification, perception and response to it, starts to be calculated from the beginning of the light or sound signal up to the change in the ground reaction force, i.e. the beginning of the ballistic movement. t_{off} , which reflects the time of situation perception and the movement performance, continues from the beginning of the light or sound signal up to the break of the signal. t_{mov} has been calculated accordingly to the formula:

$$t_{mov} = t_{off} - t_{lat}$$

The testing data have been grouped considering the investigative group, the kind of the signal and the position of sensors. The analysis of the data has been conducted evaluating the dependable variables t_{lat} , t_{mov} , t_{off} .

2.2.4. Statistical analysis

The statistical analysis of the data has been carried out using the programs SPSS 11.0 and Microsoft Excel 2003.

The equivalence of real and normal distribution has been verified using one sample Kolmogorov and Smirnov test. To establish the differences of the means of the dependent variables between investigative groups, the one factor analysis of variance (One – Way ANOVA) and the Post Hoc Tukey HSD test has been used. To establish the difference of the dependent variable means of one investigative group under different experimental conditions, the analysis of variance of blocked data has been applied (Repeated measures). The results are submitted as standard errors and mean values of equilibrium, simple and psychomotor reactions.

Correlation between the factor and features being investigated, and, also, between the dependent variables has been established using the Pearson coefficient.

The chosen level of significance has been $p < 0.05$.

2.3. Organization of study

The research has been organized during three stages of laboratory experiment: E, SR and PMR testing. The same subjects have participated during all testings. Prior to the every stage of a laboratory experiment the subjects were informed repeatedly on the course of testing.

During the first stage of the experiment, the dependence of equilibrium parameters on degree of visual impairment has been tested. During the survey, the COP pathway length of the subjects, COP displacements along the sagittal and transversal axis, sway amplitudes at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, and of 1 – 2 Hz have been established during four postures, with the visual information and having it eliminated. The results of every dependent variable investigation have been divided concerning the investigative group and the posture, during which the posturogram has been registered. We have analysed the differences in average values of dependent variables between investigative groups. We have established the influence of visual impairment on COP stability, interdependency between the degree of visual impairment and COP oscillations at different frequency ranges, and the foot stance aspect of the change in equilibrium values.

The courses of the second and the third stages have been analogous. During these stages the subjects responded to the light and sound signals. During both, the second and the third stages of the experiment, the subjects from group B performed the task responding to the sound signals, and the subjects from groups L and S were responding to the light and sound signals. During the second and the third stages of the experiment the subjects from group B performed 10 trials, and the subjects from L and S groups performed 20 trials, when the SR duration has been registered and that of PMR components as well. During these experiments we have analysed the differences in average values of dependent variables of the investigative groups, we analysed interconnection between SR and PMR duration and vision.

III. RESULTS

3.1. The results of equilibrium testing

3.1.1. The vision aspect of equilibrium analysis

The relation between the equilibrium values of the subjects from group S and their vision sensory system with the visual information participating, and blindfolded has been evaluated considering the COP displacements along the sagittal and transversal axis at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, and 1 – 2 Hz and the average values of COP pathway length.

A tendency of increase in the average values with blindfolded eyes has been observed when analyzing the testing results of all equilibrium values. The average values of COP movement pathway length (s) one the most informative values, when evaluating the vision influence on the equilibrium control, show significant increase during every posture with blindfolded eyes ($p < 0.01$) (Fig.5).

The equilibrium values and afferential information of the vision of group S are correlated. All values of the equilibrium and visual information in equilibrium control and blindfolded eyes are correlated by negative relationship. The correlation coefficients indicate the significant correlation (Table 3).

Table 3. The correlation coefficients between the equilibrium values of the sighted subjects and visual information participation in the equilibrium control. p – significance level.

Equilibrium values	Correlation coefficients	p
Δx	- 0.33	< 0.0001
Δy	- 0.42	< 0.0001
s	- 0.42	< 0.0001
x 0 – 0.7 Hz	- 0.33	< 0.0001
x 0.7 – 1 Hz	- 0.39	< 0.0001
x 1 – 2 Hz	- 0.30	= 0.001
y 0 – 0.7 Hz	- 0.42	< 0.0001
y 0.7 – 1 Hz	- 0.42	< 0.0001
y 1 – 2 Hz	- 0.41	< 0.0001

Correlation between the equilibrium values of group S and the data of visual acuity have not been established. x 0 – 0.7 Hz, x 0.7 – 1 Hz and the visual acuity are linked by a very weak, insignificant correlation link (respectively, $r = 0.11$, $p > 0.05$).

To investigate the influence of visual impairment degree on the equilibrium values of group L, we evaluated the change in equilibrium values during eight postures, and with visual information or having it eliminated. The analysis of the testing results has shown that all equilibrium values of group L have a tendency to increase when comparing postures 1 and 2, 4 and 5 ($p < 0.01$), however, significant differences between equilibrium values with visual information participation (postures 1, 3, 5, 7) and with blindfolded eyes (postures 2, 4, 6, 8), have not been observed (Fig.3, Fig. 4, Fig. 5).

The analysis of change in COP amplitude of group L at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz highlighted the same tendencies in change of values (Fig.6 – 11). Significant changes in equilibrium values along the sagittal and transversal axis have been observed between postures 4 and 5. Whereas change in visual information has not caused significantly differing equilibrium values.

Correlation between equilibrium values of group L and visual acuity data have not been established. There is a very weak, insignificant correlation between y 0.7 – 1 Hz and visual acuity ($r = 0.1$, $p > 0.05$).

Correlation coefficients between equilibrium values of group L, Δy ($r = 0.15$, $p > 0.05$), s ($r = 0.24$, $p < 0.05$), x 0.7 – 1 Hz ($r = 0.13$, $p > 0.05$), x 1 – 2 Hz ($r = 0.11$, $p > 0.05$), y 0 – 0.7 Hz ($r = 0.12$, $p > 0.05$), y 0.7 – 1 Hz ($r = 0.13$, $p > 0.05$), y 1 – 2 Hz ($r = 0.14$, $p > 0.05$) and vision afferential information in the control of equilibrium, i.e., opened and blindfolded eyes indicate a very weak or a weak, insignificant correlation.

When evaluating the equilibrium dependence of the subjects from group B on visual impairment degree, we did not observe any significant differences during postures 1, 3, 5, 7 and 2, 4, 6, 8, thus we used only equilibrium values during postures 1, 3, 5, 7 for the analysis.

Correlation between the equilibrium values and visual impairment degree, when the vision does not participate, is weak and insignificant. The correlation between all equilibrium values, with opened eyes and the visual impairment degree is weak and insignificant ($r = 0.36$, $p < 0.01$).

Average values Δx of group L during all postures, except posture 8 (68 ± 7 mm) are the highest. 1 (31 ± 1 mm), 3 (39 ± 2 mm), 5 (77 ± 11 mm), 6 (72 ± 11 mm), 7 (76 ± 10 mm) are the highest. They are significantly higher than those of group S during postures (respectively 24 ± 1 mm, 28 ± 3 mm, 30 ± 2 mm, 44 ± 2 mm, 35 ± 3 mm, $p < 0.05$) and during posture 5 they are significantly better than those of group B (50 ± 5 mm, $p < 0.05$) (Fig. 3). Average values Δx of group S during all postures, except 4 (34 ± 2 mm) are the least. During posture 4 average value Δx of group B (32 ± 4 mm) is insignificantly less than Δx of group S ($p > 0.05$). The average value Δx of group B during posture 8 (74 ± 13 mm) is insignificantly higher than that of group L (68 ± 7 mm) ($p > 0.05$).

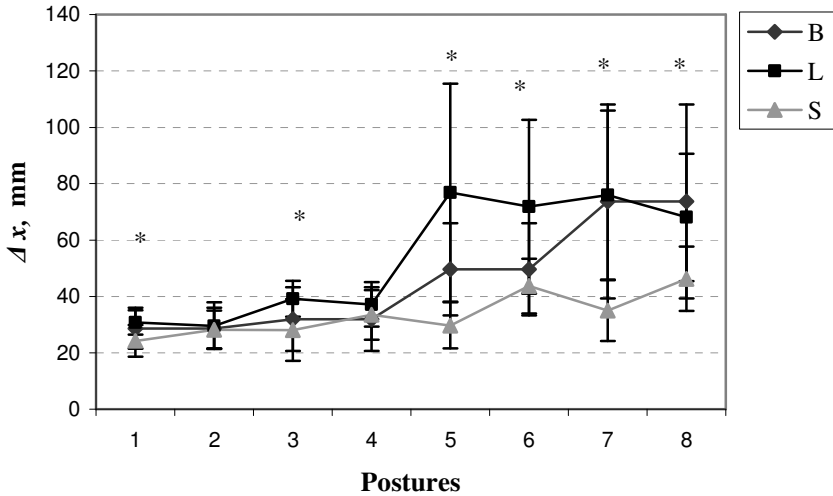


Fig. 3. The visual impairment degree aspect of the change in average values Δx for the investigative groups of sighted, legally blind and totally blind subjects. * – the differences in investigative groups of legally blind and sighted subjects during postures 1, 3, 5, 6, 8, the differences in legally blind and totally blind subjects during posture 5 are statistically significant ($p < 0.05$).

Average values Δy of group L during all postures, except posture 2 (31 ± 1 mm) are the highest. During postures 1 (30 ± 1 mm, $p < 0.05$), 3 (40 ± 1 mm, $p < 0.01$), 5 (65 ± 6 mm, $p < 0.01$) and 7 (65 ± 5 mm, $p < 0.01$) average values Δy of group L significantly differ from average values Δy of group S (respectively 25 ± 1 mm, 26 ± 2 mm, 34 ± 3 mm, 35 ± 3 mm) (Fig.4). The average values Δy of group S during all postures, except 2 (32 ± 2 mm) and 6 (56 ± 4 mm), are the least. The average values Δy during posture 2 of groups B (29 ± 2 mm) and L (30 ± 2 mm) are less than average value Δy of group S ($p > 0.05$). Average value Δy of group B during posture 6 (55 ± 5 mm) is less than that of group S ($p > 0.05$).

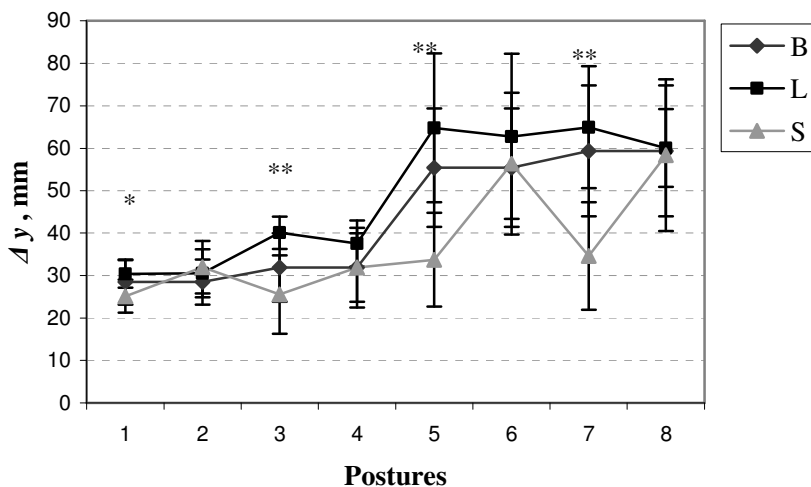


Fig. 4. The visual impairment degree aspect of the change in average values Δy for the investigative groups of sighted, legally blind and totally blind subjects. * – the differences in investigative groups of legally blind and sighted subjects are statistically significant ($p < 0.05$), ** – the differences in legally blind and totally blind subjects are statistically significant ($p < 0.01$).

Values s of group L during all postures, except 2 (897 ± 78 mm) and 4 (1086 ± 91 mm) ($p > 0.05$), are significantly higher than those of groups B and S (1, 6, 8, $p < 0.05$; 3, 5, 7, $p < 0.01$) (Fig.5).

The values s of group S during postures 3 (592 ± 36 mm), 5 (1207 ± 95 mm), 7 (1355 ± 106 mm) significantly less ($p < 0.01$) than those of group B (respectively 926 ± 58 mm, 1623 ± 40 mm, 2119 ± 128 mm).

The average values s of group S during postures 2, 4, 6 (800 ± 26 mm, 1010 ± 71 mm, 1978 ± 131 mm) are insignificantly higher than those corresponding s values of group B (757 ± 34 mm, 32 ± 2 mm, 1623 ± 40 mm). s values of groups B and S during posture 8 are equal (respectively 2119 ± 128 mm, 2118 ± 149 mm).

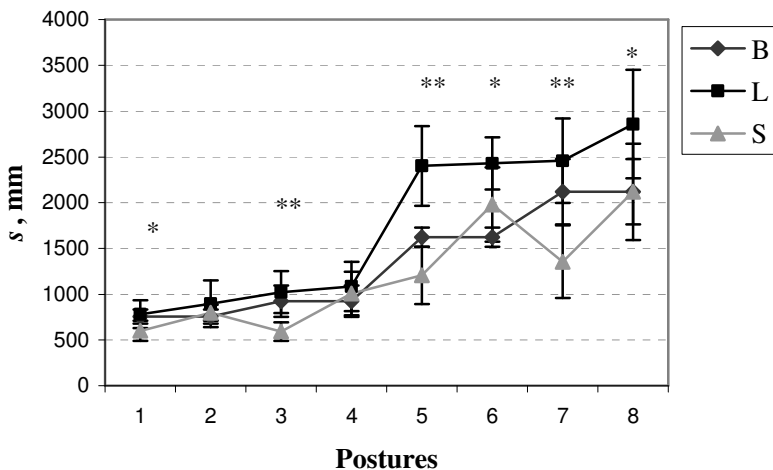


Fig. 5 The visual impairment degree aspect of the change in average values s for the investigative groups of sighted, legally blind and totally blind subjects. * – the differences in investigative groups of legally blind and sighted subjects are statistically significant ($p < 0.05$), ** - the differences in investigative groups of legally blind and sighted subjects during postures 3, 5, 7 and the differences in investigative groups of totally blind and sighted subjects during postures 3, 5, 7 are statistically significant ($p < 0.01$).

The COP oscillation amplitude along the sagittal axis at frequency range of 0 – 0.7 Hz is the highest (during postures 1, 3, 7, 8, $p < 0.05$; postures 4, 5, 6, $p < 0.01$) (Fig. 6). Group S values x 0 – 0.7 Hz during postures 1 (173 ± 7 mm, $p < 0.05$), 5 (176 ± 14 mm, $p < 0.01$), 6 (253 ± 12 mm, $p > 0.05$), 7 (217 ± 20 mm, $p < 0.05$), 8 (249 ± 16 mm, $p > 0.05$) are less than the corresponding values of group B (213 ± 14 mm, 279 ± 28 mm, 279 ± 28 mm, 312 ± 26 mm). During postures 2, 3, 4 group B values x 0 – 0.7 Hz are significantly less than the corresponding values of group S.

The COP oscillation amplitude of group L along the sagittal axis at frequency range of 0.7 – 1 Hz during postures 1 (67 ± 4 mm), 3 (93 ± 8 mm), 4 (100 ± 10 mm) are insignificantly and during postures 5 (210 ± 24 mm), 6 (197 ± 17 mm) significantly higher than the COP oscillation amplitude of groups B and S (Fig.7).

Group S average values x 0.7 – 1 Hz during postures 1 (51 ± 3 mm, $p > 0.05$), 5 (89 ± 5 mm, $p < 0.01$), 7 (100 ± 6 mm, $p < 0.01$), 8 (115 ± 7 mm, $p < 0.01$) are less than group L and B corresponding values. During postures 2 (75 ± 6 mm) and 4 (95 ± 7 mm) the COP oscillations of group S at frequency range of 0.7 – 1 Hz are insignificantly higher than those of group B (respectively 66 ± 6 mm, $79 \pm$

6 mm). During postures 2, 3, 4, differences in means $x 0.7 - 1$ Hz are statistically insignificant.

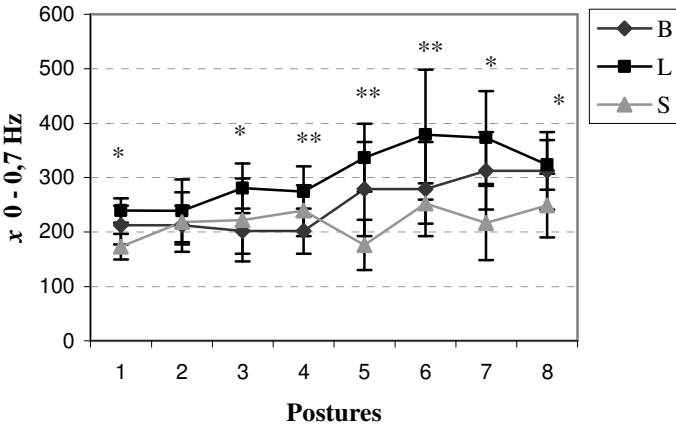


Fig. 6. The visual impairment degree aspect of the change in average values $x 0 - 0.7$ Hz during various postures for the investigative groups of sighted, legally blind and totally blind subjects. * - the differences in the investigative groups of sighted, legally blind and totally blind subjects are statistically significant ($p < 0.05$), ** - the differences in the investigative groups of sighted, legally blind and totally blind are statistically significant ($p < 0.01$).

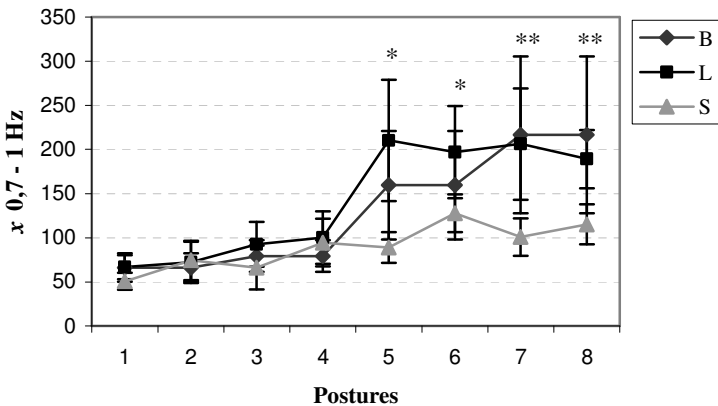


Fig. 7. The visual impairment degree aspect of the change in average values $x 0.7 - 1$ Hz during various postures for the investigative groups of sighted, legally blind and totally blind subjects. * - the differences in the investigative groups of legally blind, sighted and totally blind subjects are statistically

significant ($p < 0.05$), ** - the differences in the investigative groups of sighted, legally blind and totally blind are statistically significant ($p < 0.01$).

During postures 1, 2, 3, 4 and 8 group B, L and S the differences in average values x 1 – 2 Hz are statistically significant (Fig. 8). During postures 5 and 6 group L average values x 1 – 2 Hz (149 ± 13 mm, 144 ± 15 mm) are significantly higher than corresponding values of group S (61 ± 4 mm, 87 ± 4 mm, $p < 0.01$).

During postures 5, 6, 7, 8 group S values x 1 – 2 Hz are the least. During postures 7, 8 the COP oscillations of group B subjects in the sagittal direction are the highest (156 ± 39 mm, $p < 0.05$; 156 ± 39 mm, $p > 0.05$).

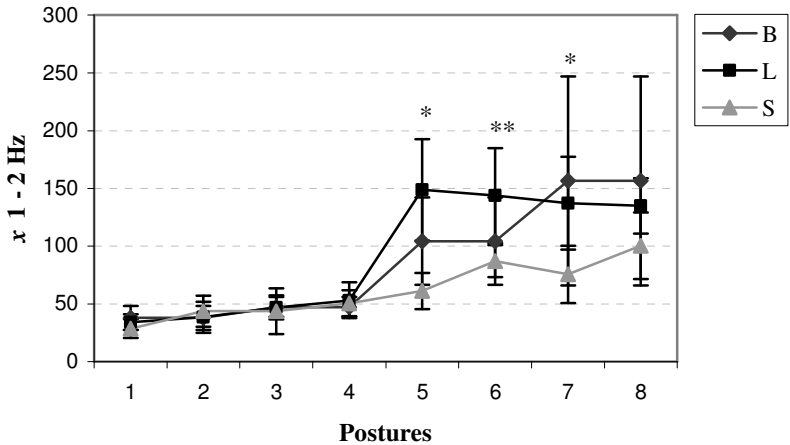


Fig. 8. The visual impairment degree aspect of the change in average values x 1 – 2 Hz during various postures for the investigative groups of sighted, legally blind and totally blind subjects. * – the differences in investigative groups of legally blind and sighted subjects during posture 5 and the differences in investigative groups of totally blind, legally blind and sighted subjects during posture 7 are statistically significant ($p < 0.05$), ** – the differences in the investigative groups of legally blind and sighted subjects during posture 6 are statistically significant ($p < 0.01$).

The amplitudes of COP oscillations of group L along the transversal axis during all postures at frequency range of 0 – 0.7 Hz, except posture 2, are the highest (Fig. 9). During postures 2, 4, 8 group B, L and S differences in average values y 0 – 0.7 Hz are statistically unreliable. Group S and B average values y 0 – 0.7 Hz are comparable during all postures. During postures 1 and 7 the values of group S (193 ± 8 mm, $p < 0.05$; 252 ± 21 mm, $p < 0.01$) are significantly less than those of group B (respectively 236 ± 16 mm, 425 ± 23 mm). During postures 2, 5, and 8, the COP displacement along the transversal axis of group S is statistically unreliably higher than that of group B.

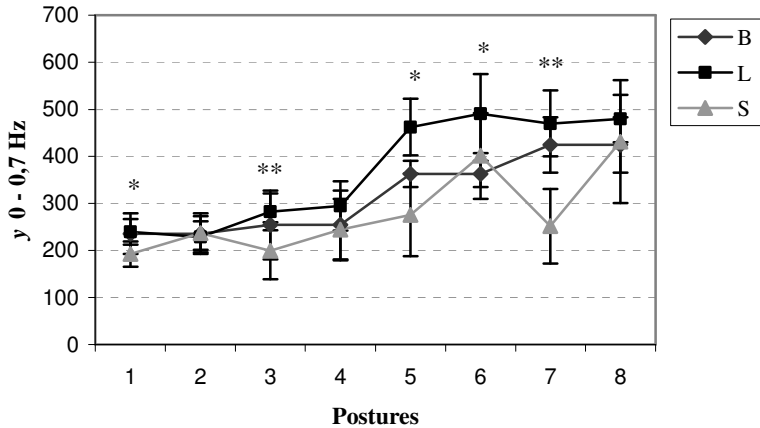


Fig. 9. The visual impairment degree aspect of the change in average values $y_0 - 0.7$ Hz during various postures or the investigative groups of sighted, legally blind and totally blind subjects. * – the differences in the investigative groups of totally blind and sighted subjects during posture 1, the differences in the investigative groups of totally blind, legally blind and sighted subjects during posture 5 and the differences in the investigative groups of legally blind and totally blind during posture 6 are statistically significant ($p < 0.05$), ** – the differences in the investigative groups of the totally blind, legally blind and sighted subjects during posture 3 and the differences in investigative groups of the totally blind and sighted subjects during posture 7 are statistically significant ($p < 0.01$).

L group average values $y_{0.7 - 1}$ Hz during all postures are the highest (during postures 3, 5, 6, 7, $p < 0.01$) (Fig. 10). Group S values $y_{0.7 - 1}$ Hz during postures 1, 3, 4, 5, 7 are less than the corresponding values of group B, still significantly differ only $y_{0.7 - 1}$ Hz during 5 and 7 postures (respectively of group S: 97 ± 7 mm, 112 ± 9 mm, of group B: 163 ± 8 mm, 203 ± 18 mm; $p < 0.01$). Group B average values $y_{0.7 - 1}$ Hz during postures 2 (72 ± 5 mm), 6 (163 ± 8 mm), 8 (203 ± 18 mm) do not differ or are unreliably higher than those of group S (respectively 74 ± 3 mm, 174 ± 13 mm, 221 ± 14 mm).

The average values $y_{0.7 - 1}$ Hz of groups B, L and S during postures 1, 2, 4, and 8 differ insignificantly.

The average values $y_{1 - 2}$ Hz during postures 1, 2, 3, 4 and 8 differ statistically insignificantly (Fig. 11). Group L values $y_{1 - 2}$ Hz during all postures except posture 2 (41 ± 4 mm), are higher than the corresponding values of groups S and B. Group S average values $y_{1 - 2}$ Hz during postures 2 (51 ± 6 mm), 4 (41 ± 2 mm), 8 (114 ± 11 mm) are insignificantly higher than the corresponding values of group B (36 ± 2 mm, 45 ± 3 mm, 105 ± 8 mm).

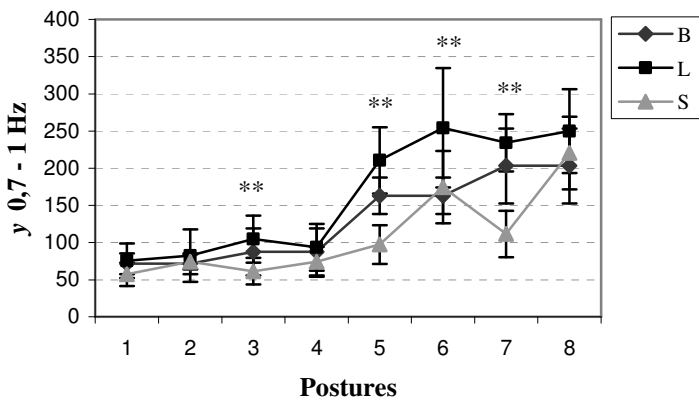


Fig. 10. The visual impairment degree aspect of the change in average values $y_{0,7 - 1 \text{ Hz}}$ during various postures for the investigative groups of sighted, legally blind and totally blind subjects. ** – the differences in the investigative groups of legally blind, totally blind and sighted subjects during postures 3, 5, 6, and 7 and the differences in the investigative groups of totally blind and sighted are statistically significant ($p < 0.01$).

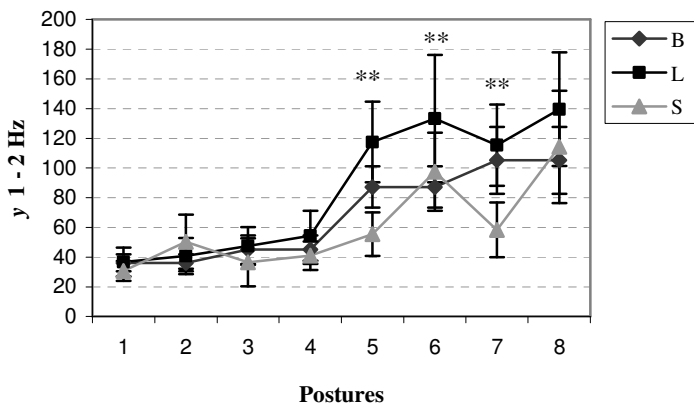


Fig. 11. The visual impairment degree aspect of the change in average values $y_{1 - 2 \text{ Hz}}$ during various postures for the investigative groups of the sighted, legally blind and totally blind subjects. ** – the differences in all investigative groups during posture 5, the differences in the investigative groups of legally blind, totally blind and sighted subjects during posture 6 and the differences in the investigative groups of legally blind and sighted subjects during posture 7 are statistically significant ($p < 0.01$).

3.1.2. The foot stance aspect of equilibrium analysis

Equilibrium values Δx , Δy , s , $x_0 - 0.7$ Hz, $x_0.7 - 1$ Hz, $x_1 - 2$ Hz, $y_0 - 0.7$ Hz, $y_0.7 - 1$ Hz, $y_1 - 2$ Hz have been estimated with the subjects standing during different postures and with visual information present or having it eliminated.

The comparative analysis of change in group S, L and B equilibrium has indicated that during postures 1, 3, 5, 7, and during 2, 4, 6, 8, the equilibrium values of group L are the highest and increase most distinctively when the foot stance changes ($p < 0.05$) (Fig. 12, 13).

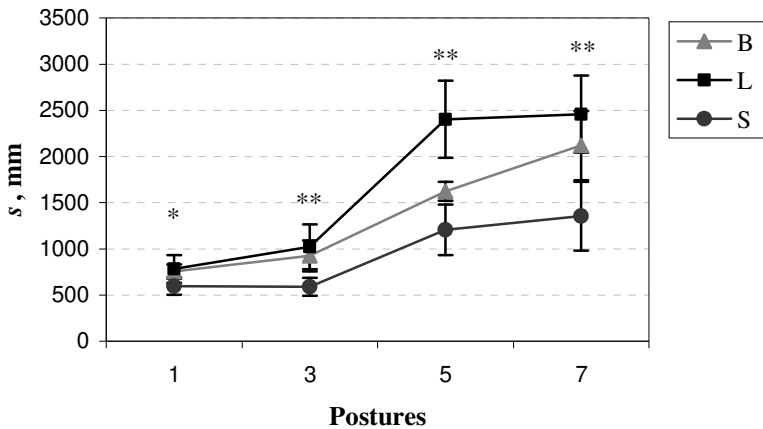


Fig. 12. The dynamics of average values s for the investigative groups of sighted, legally blind and totally blind subjects during postures 1, 3, 5 and 7 * – the differences in the investigative groups of legally blind and sighted subjects are statistically significant ($p < 0.05$), ** - the differences in the investigative groups of legally blind, sighted and totally blind subjects during postures 3, 5 and 7 are statistically significant ($p < 0.01$)

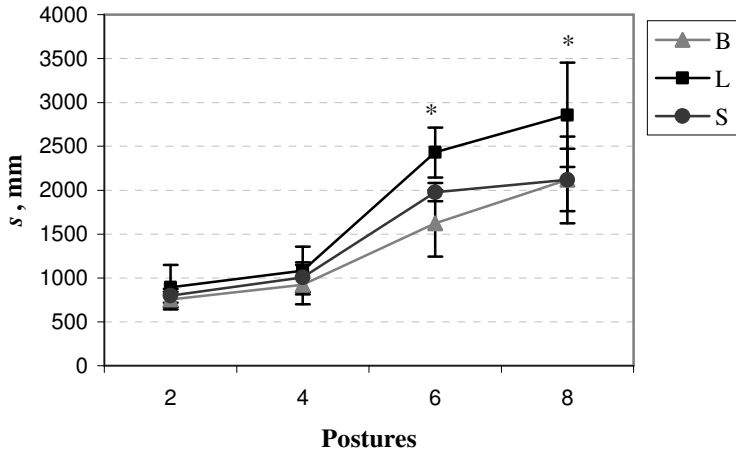


Fig. 13. The dynamics of average values s for the investigative groups of sighted, legally blind and totally blind subjects during postures 2, 4, 6 and 8. * – the differences in investigative groups of legally blind and sighted subjects are statistically significant ($p < 0.05$).

The equilibrium values Δx , Δy , s , x 0 – 0.7 Hz, x 0.7 – 1 Hz, x 1 – 2 Hz, y 0 – 0.7 Hz, y 0.7 – 1 Hz, y 1 – 2 Hz of subjects from groups S, L and B are correlated with the foot stance (Table 4).

Table 4. The correlation coefficients (r) between the equilibrium and foot stance of the sighted, legally blind and totally blind subjects. The statistically significant values of r are provided in the table ($p < 0.01$).

	Δx	Δy	s	x 0–0,7 Hz	x 0,7–1 Hz	x 1–2 Hz	y 0–0,7 Hz	y 0,7–1 Hz	y 1–2 Hz
<i>S group Feet stance</i>	0.50	0.52	0.73	0.23	0.60	0.71	0.54	0.70	0.61
<i>L group Feet stance</i>	0.52	0.60	0.82	0.45	0.67	0.72	0.75	0.75	0.74
<i>B group Feet stance</i>	0.57	0.64	0.89	0.49	0.66	0.57	0.73	0.77	0.83

3.2. The results of the simple reaction testing

The comparative analysis of the SR values of groups S, L and B to the light and to the sound has shown that the sighted subjects statistically reliably more rapidly (216 ± 5 ms) respond to a light stimuli than the legally blind subjects (296 ± 7 ms, $p < 0.01$) (Fig. 14). Still the average duration values of the reaction to the light of the sighted subjects significantly do not differ from the average values of the reaction to the sound stimuli of those who are totally blind (215 ± 4 ms, $p > 0.05$).

The average values of the simple reaction duration to the sound of the subjects from group L are the highest (234 ± 5 ms), when comparing to the values of the reaction to the sound for subjects from groups S (193 ± 3 ms) and B (215 ± 4 ms, $p < 0.05$).

The values of the simple reaction duration to the sound of the subjects from group S (193 ± 3 ms), are the least, analogically to the results of the simple reaction to the light ($p < 0.01$). Although there exists a statistically significant difference in the values of reaction duration to the sound between the subjects from groups S and B, yet it is noticeable that those average values are comparable.

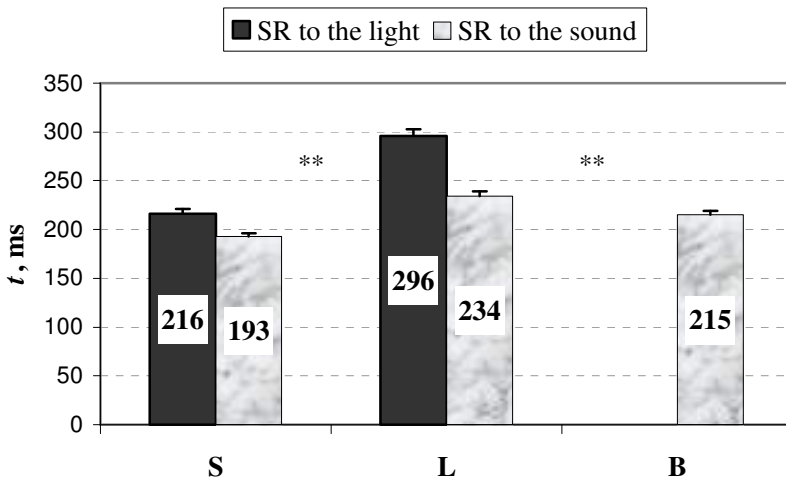


Fig. 14. The average values of the simple reaction duration to the light and sound for the investigative groups of sighted, legally blind and totally blind subjects. t – the simple reaction duration (ms), ** – the differences between groups are statistically significant.

While evaluating the correlation between all groups in the meaning of different degree of visual impairment, we have noticed that individual duration value of SR to the light and sound of the sighted and legally blind subjects are not associated with the data of visual acuity, still the reaction duration of both group S and group L correlates with the degree of visual impairment (Table 5).

Table 5. The values of the correlation coefficient (r) between the simple reaction duration and the degree of visual impairment. p – significance level.

Group, Visual impairment degree	SR to the light	p	SR to the sound	p
S	0.6	0.000	0.2	0.000
L	0.5	0.000	0.2	0.000
B	0.6	0.000	0.3	0.000

3.3. The results of psychomotor reaction testing

To establish the peculiarities of the psychomotor reaction to the light and sound of the subjects that have been divided according to the different degree of visual impairment, we have registered and analyzed the entire duration of the psychomotor reaction and the latent and movement durations as well.

All values of PMR to the light of group S are significantly better than those of group L (Fig. 15). The sighted subjects during PMR to the light more rapidly perform a ballistic movement (310 ± 8 ms), and the latent duration is shorter (304 ± 7 ms) as well as the entire PMR duration (612 ± 9 ms), in comparison to the legally blind (respectively, 404 ± 12 ms, 430 ± 16 ms, 837 ± 20 ms).

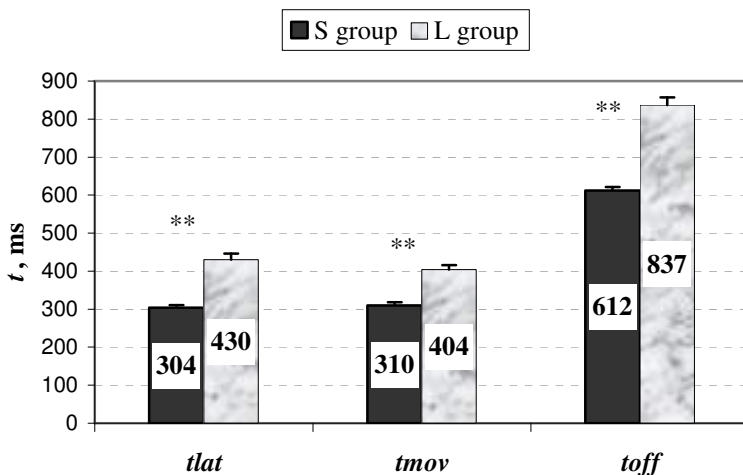


Fig. 15. The average values of the psychomotor reaction to the light for the investigative groups of the sighted and legally blind subjects. t – duration (ms), t_{lat} – the latent duration of the psychomotor reaction, t_{mov} – the movement duration of the psychomotor reaction, t_{off} – the total duration of the psychomotor reaction, ** – the statistically significant differences between groups ($p < 0.01$).

The average values of the latent duration of PMR to the sound of the sighted, legally blind and totally blind subjects significantly differ ($p < 0.01$) (Fig. 16). The latent period of PMR to the sound of group S subjects is the shortest (257 ± 6 ms) in comparison to those of groups L (459 ± 29 ms) and B (307 ± 16 ms) ($p < 0.01$).

The differences in the average values of the motor stage duration of PMR to the sound of groups S, L and B are statistically insignificant.

The values of the total duration of PMR to the sound are analogous to the values of the latent duration of PMR to the sound. In this case the total PMR duration of the sighted subjects (704 ± 27 ms) is significantly shorter than those of the legally blind (941 ± 36 ms) and totally blind subjects (772 ± 36 ms) ($p < 0.01$). Correspondingly, the subjects of group L respond to the sound stimuli most slowly.

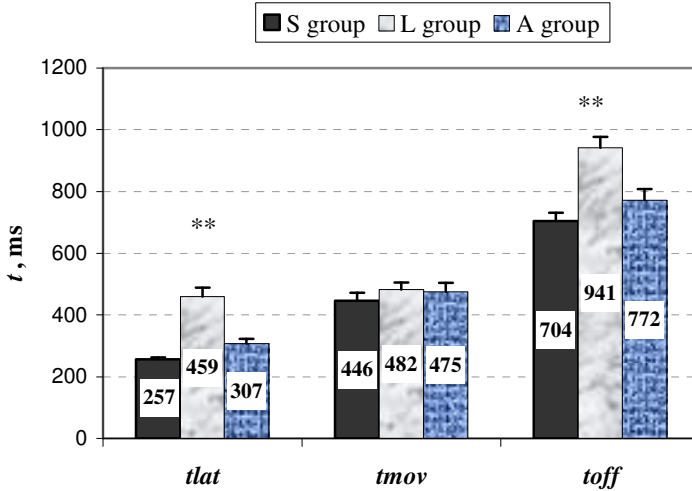


Fig. 16. The average values of the psychomotor reaction to the sound for the investigative groups of sighted, legally blind and totally blind subjects. t – duration (ms), t_{lat} – the latent duration of the psychomotor reaction, t_{mov} – the movement duration of the psychomotor reaction, t_{off} – the total duration of the psychomotor reaction, ** – the statistically significant differences between groups ($p < 0.01$).

The average values of the latent, movement and total durations of PMR to the light and sound of the sighted subjects do not differ during the response process to the light and sound sensors being at different positions ($p > 0.05$).

The total duration of PMR to the light of the sighted subjects is significantly longer while responding to the sensors I and VI that are placed at 0° (1005 ± 97 ms), than to the III and IV that are placed at 72° (785 ± 44 ms, $p < 0.05$). The similar tendency in the change of results is noticeable during PMR to the sound as well: the total PMR duration is significantly longer while responding to the I and VI sensors that are placed at 0° (1082 ± 114 ms), than to the III and IV sensors that are placed at 72° (754 ± 52 ms, $p < 0.05$) (Fig.17).

The movement duration of PMR to the sound while responding to the I and VI sensors (621 ± 87 ms), is also longer than while responding to the III and IV sensors (392 ± 52 ms, $p < 0.05$).

The average values of PMR to the sound of the totally blind subjects while responding to the sound stimuli of different locations differ statistically insignificantly.

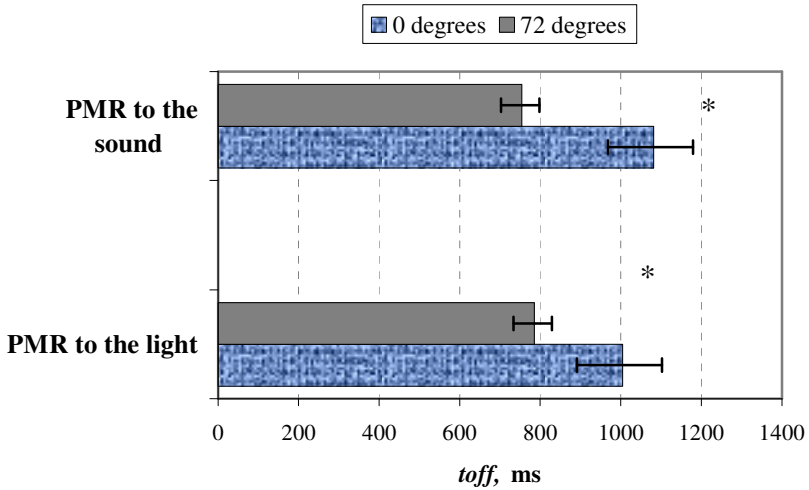


Fig. 17. The total duration – average values of the psychomotor reaction to the sound of the investigative groups of the legally blind subjects while responding to the stimuli of different location, t_{off} – the total duration of the psychomotor reaction, * – the statistically significant differences between groups ($p < 0.01$).

The correlation coefficients show that the total duration of PMR to the light and sound of the subjects from group S is stronger related to the duration of movement than to the latent one. The correlation between the latent and movement durations of PMR of group L and the total PMR duration are analogous to the correlation coefficients of subjects from group S, however, only during the PMR to the light. While responding to the sound stimuli, the total PMR duration of group L depends more on the latent duration than on the movement one. The total duration average values of the totally blind PMR correlate only with the average values of movement duration. The significant correlation between PMR values of groups S, L and B have been established.

There has not been noticed any correlation between PMR values of groups S and L and indications of individual visual acuity, still the PMR values of all groups are related to the degree of visual impairment.

The correlation between latent, movement duration of PMR to the light and the degree of visual impairment is insignificant ($r = 0.42$, $p < 0.01$), and the correlation between total PMR duration and the degree of visual impairment is more significant ($r = 0.6$, $p < 0.01$).

The correlation between latent duration of PMR to the sound, the total PMR duration and the degree of visual impairment is insignificant ($r = 0.4$, $p < 0.01$).

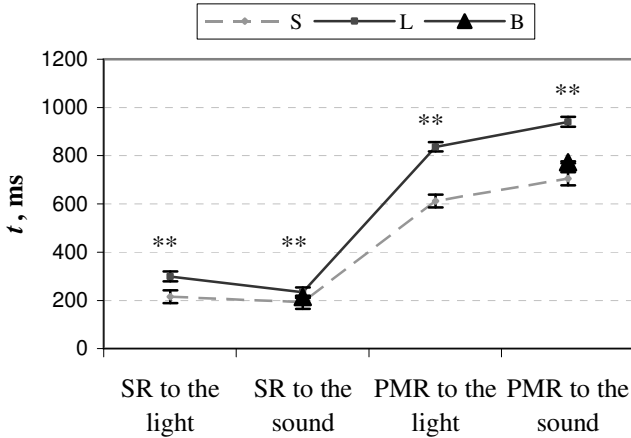


Fig. 18. The average values of simple reaction t and psychomotor reaction t_{off} of the investigative groups of the sighted, legally blind and totally blind subjects. ** - the differences between the average values t and t_{off} of the investigative groups are statistically significant ($p < 0.01$).

The average values of SR to the light t of the sighted subjects (216 ± 5 ms) and PMR to the light t_{off} (612 ± 9 ms) are significantly less than the corresponding average values of the legally blind subjects (296 ± 7 ms, 837 ± 20 ms, $p < 0.01$) (Fig. 18). The average values of SR to the sound t (193 ± 3 ms) of group S and those of PMR to the sound t_{off} (704 ± 27 ms) are significantly less as well than those corresponding values of groups L and B (group L - 234 ± 5 ms, 941 ± 36 ms; group A - 215 ± 4 ms, 772 ± 36 ms, $p < 0.01$).

Equilibrium values Δx , Δy and s considered to be the most informative factors. Δx , Δy and s also the SR and the total PMR duration are correlated. The total duration of PMR to the light of group L is related to Δy ($r = 0.25$, $p < 0.05$), the total duration of PMR to the sound is related to Δy ($r = 0.23$, $p < 0.05$). The correlation between simple reaction duration to the light and sound of group L and Δx , Δy , s is statistically insignificant.

The duration of simple reaction to the light of group S subjects correlates with equilibrium value Δy ($r = 0.23$, $p < 0.05$), to the length of COP pathway ($r = 0.30$, $p = 0.01$). The duration of SR to the sound of group S is related to Δy ($r = 0.26$, $p < 0.05$), and to the length of COP pathway ($r = 0.25$, $p < 0.05$). The correlation between total duration of PMR to the light and sound of group S and Δx , Δy and s is statistically insignificant.

IV. DISCUSSION

4.1. The relationship among the equilibrium values and the degree of visual impairment

Three sensory systems take part in the equilibrium control of a human being, thus a possibility for their interaction exists permanently, allowing replace an insufficient or disordered activity of one system by the activity of another sensory system. The group of the sighted subjects has had a permanent possibility to duplicate an eliminated sensory system by another one, for instance, in case of visual information being eliminated, the senses of vestibular and proprioception systems remain active (Winter, 1995). Thus, having eliminated the visual information from the equilibrium control, equal conditions to maintain a static balance appear for the subjects with vision disorders and for the sighted subjects. At the same time we can assess the importance of visual information for the sighted and legally blind subjects, and make a presumption in connection with the compensatory role of proprioception and vestibular systems for the equilibrium control of adolescents with vision disorders.

The scientists maintain (Nougier, 1998), that a classical value for assessing the contribution of the vision sensory system to the equilibrium control is Romberg's coefficient, i.e. a ratio of the equilibrium value with vision participating to the one of the same quantity, achieved with blindfolded eyes. In case of our research, while evaluating the equilibrium testing results of the totally blind, and while comparing the equilibrium values of different groups, the Romberg's coefficient is insignificant.

We have evaluated the vision sensory system influence on the equilibrium considering the change in equilibrium values Δx , Δy , s , x 0 – 0.7 Hz, x 0.7 – 1 Hz, x 1 – 2 Hz, y 0 – 0.7 Hz, y 0.7 – 1 Hz, y 1 – 2 Hz with opened and blindfolded eyes.

The results of equilibrium testing for the sighted subjects promote the presumption made by Sologubov et al. (2000), Collins and De Luca (1995), that COP displacement along the sagittal and transversal axis and the length of COP pathway present themselves as the most informative factors when assessing the influence of vision on the equilibrium control.

Statistically the most significant differences between average values of equilibrium with opened and blindfolded eyes have become highlighted with COP swaying along the sagittal and transversal axis, and in the results of COP pathway length.

The sighted subjects are significantly less stable along the transversal axis than along the sagittal axis. The spectral analysis of COP oscillations in transversal direction has confirmed it as well: at the frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz the COP oscillations in the sagittal direction are less than in the transversal one. Nougier (1998) maintains that the peripheral vision influences

oscillations in the transversal direction, still, in our case, the eyes have not been blindfolded, moreover, the sighted subjects had not had any change in the visual field.

The results of equilibrium values of the sighted subjects, show a tendency of increase in values when the eyes are blindfolded. After elimination of the visual information, proprioception and vestibular information become dominant. The scientists maintain that after elimination of visual information, proprioception becomes especially important for the equilibrium control (Duarte et al., 2000). Still, the equilibrium testing results make us think that the last-mentioned sensory system is not able to compensate the visual information. We agree with Guerraz et al. (2000) that the vision system is essential factor for the equilibrium control.

The importance of vision influence on the equilibrium control is confirmed as well by the fact that correlation exist between equilibrium values and vision participation in the process of balance maintaining and its elimination.

The results of the experiment have shown that the equilibrium values of the legally blind subjects do not depend on vision participation in equilibrium control or on the blindfolded eyes. Both with opened and blindfolded eyes, the average values of equilibrium do not differ statistically significantly. We make a presumption that that the contribution of both visual and proprioception and vestibular information to balance maintenance is similar. Thus, we are not able to distinguish any in equilibrium control domineering sensory system. These propositions are confirmed by the fact that there are no correlation between equilibrium values and vision participation in equilibrium control and data of visual acuity.

COP oscillations along the sagittal and transversal axis of the legally blind subjects differ unreliably and are markedly greater than those of the sighted or totally blind subjects. We presume that this instability in both directions, with vision participating in equilibrium control, is determined by disorders in central and peripheral vision, as the peripheral vision effects COP oscillations along the sagittal axis, and the central one – along the sagittal and the central axis (Nougier, 1998).

The comparative analysis of equilibrium testing results of the sighted, legally blind and totally blind subjects helps to reveal the influence of visual impairment degree on equilibrium control.

The COP displacement along the sagittal and transversal axis, the average values of COP pathway length, also the average values of COP oscillation amplitude at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz indicate that the legally blind subjects maintain the balance worse than the sighted and totally blind subjects. As equilibrium maintenance with opened eyes and blindfolded eyes changes insignificantly, we presume that proprioception and vestibular information that take part in equilibrium control compensate the consequences of blindfolded eyes, still the importance of vision sensory system remains inconsiderable.

The COP displacement along the transversal axis, and the amplitude along the transversal axis at frequency ranges of 0 – 0.7 Hz and 1 – 2 Hz blindfolded

eyes, of the legally blind subjects are statistically insignificantly less than those of the sighted and totally blind subjects. This change in equilibrium values, depending on vision, allows presuming that vision role in equilibrium control of the legally blind adolescents is an important factor, still the vision sensory system does not predominate among other sensory systems.

As we have mentioned above, the COP displacement along the sagittal and transversal axis and the length of COP pathway have come to be the most informative values while evaluating the vision influence on equilibrium control. The results of our research have indicated that the COP displacement and the pathway length of the totally blind and the sighted subjects do not differ significantly. These results are confirmed by the spectrum analysis of COP sway amplitude as well. The sighted subjects with opened eyes maintain the balance better than legally and totally blind subjects. Still, during postures 2, 4, 6, 8 eyes blindfolded, the equilibrium values of the totally blind and sighted subjects show considerable change – COP position of totally blind become more stable, thus, the totally blind maintain the balance better than the sighted subjects.

We can make a conclusion that the prevailing factor in the static equilibrium control of the totally blind comes to be proprioception and vestibular information, and the activity of these sensory systems compensate the lack of visual information successfully.

The vision aspect of spectral analysis of COP sway amplitude at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz has shown that along both, sagittal and transversal, axis at frequency of 1 – 2 Hz the most informative values appear in the least amount. We presume that the frequency of 1 – 2 Hz is not an informative one for the evaluation of equilibrium values dependence on a vision disorder. Thurner et al. (2000), Giacomini et al. (1998) maintain that frequency of 1 Hz and more reflects the activity of CNS during equilibrium control, and Diener et al. (1982) maintain that frequency of 1 Hz may be the marginal one for the activity of vision sensory system during equilibrium control.

The correlation between the degree of vision impairment and equilibrium values with eyes opened and blindfolded eyes have shown that the degree of visual impairment influences the equilibrium only then when the vision sensory system takes part in equilibrium control.

4. 2. The relationship among the equilibrium values and the foot stance

Most frequently, the proprioception is referred to as one of the most important sensory systems that take part in equilibrium control beside vision (Jeka et al., 2004). Also, it is maintained that the somatosensory information on the contact with the support plane presents itself as an extremely important factor to equilibrium control (Jeka et al., 1998).

The dependence between foot stance related to proprioception in equilibrium control and vision has not been cleared, and the change in this interaction

depending on the degree of vision impairment as well. To reveal these particularities of interaction between a.m. sensory systems in equilibrium control, we have evaluated the change in equilibrium values of the sighted, legally blind and totally blind subjects while standing during different postures with opened eyes or blindfolded eyes.

The analysis of equilibrium value dependence on foot stance of the sighted subjects has shown that with both opened and blindfolded eyes, the equilibrium values show increase while changing position from the side-by-side stance (postures 1, 2, 3, 4) to the tandem stance (postures 5, 6, 7, 8). The equilibrium values are increasing extremely markedly while changing the foot stance without visual information in equilibrium control. In this case, the foot stance and the proprioception that is related to the foot stance become especially important to equilibrium control. The results of the research have confirmed the propositions of scientists that somatosensory information on the contact with the support plane comes to be of extremely importance to equilibrium control (Jeka et al., 1998; Peterka, Loughlin, 2004).

We have noticed that with opened eyes, the number of equilibrium values that significantly differ and depend on the support is less in comparison to the situation when COP oscillations are being registered with blindfolded eyes. Thus we agree with Peterka (2002), Guerraz et al. (2001) and Latash (1998) on the statements that, yet, the primary role in equilibrium correction for the sighted subjects falls on vision, and the afferential, proprioception information is not considerably important when visual information takes part in equilibrium control.

The dependence between the equilibrium values of the legally blind subjects and foot stance with proprioception information is slightly different from the one of the sighted subjects. The comparative analysis for equilibrium values with opened eyes has shown that the equilibrium values of the legally blind are more related to the foot stance than those of the sighted subjects. We can make a presumption that when vision worsens, the partial visual information in equilibrium control is complemented by proprioception, and the proprioception information gains increasingly greater importance in maintaining equilibrium.

The analysis of the interaction between the foot stance and equilibrium values of the totally blind has shown that the dynamics of equilibrium values of totally blind subjects while foot stance is changing, is analogous to the change in equilibrium values of the sighted adolescents. Thus, equilibrium values show statistically significant increase while changing position from the side-by-side stance to the tandem stance.

The results of our study are related to the survey conducted by Winter (1995) during which it was noticed that COP sway amplitude when in tandem stance is higher than in side-by-side stance.

The degree of equilibrium stability of a human body during various postures is determined by its static equilibrium stability value – stability coefficient (body capability to resist the equilibrium disturbance in certain direction), and by the dynamic value – stability angle (body capability to recover the position) (Hall,

1999). Both values depend on the height of body COM above the support and the length of gravity arm.

Equilibrium values of the sighted, legally blind and totally blind subjects during postures 1 and 3, 2 and 4, 5 and 7, 6 and 8 do not depend on arm position. Nonexistence of statistically significant differences allows us to conclude that changes in arm position cause insignificant change in COP position and in stability coefficient that is related to it as well.

While comparing postures 1 and 3, 5 and 7, the equilibrium values change very slightly and these results of the research promote the acceptance of Latash (1998) statement, concerning CNS, the one from other sensory systems, which take part in equilibrium control, giving priority to the visual input.

The all average equilibrium values, except the length of COP pathway, of legally blind adolescents are less when the arms are stretched. Although these factors differ insignificantly, they allow us to think that visual information is predominant for the sighted subjects, and the proprioception prevails in equilibrium control of legally blind adolescents. We presume that, while arm position is changing, the muscles of upper limbs and waist are involved into COP position stabilization, thus, more inferential proprioceptive information is gained on body segment position in space, and this helps to perform equilibrium control more effectively.

According to the scientists (Chiari et al., 2002), there are no standardized protocols on the research work in the field of investigation of equilibrium dependences on foot stance, anthropometrical indications and other biomechanics values. The results of our research allow us to think that when investigating equilibrium factors, it is purposive to register the COP sway while standing during different postures – side-by-side stance and tandem stance, still the change in arm position do not provide any informative knowledge about the peculiarities of equilibrium control.

When analyzing the change in COP position in the sagittal and transversal direction at frequency ranges of 0 – 0.7 Hz, 0.7 – 1 Hz, 1 – 2 Hz we have noticed that at frequency range of 0 – 0.7 Hz the number of statistically significant results is the least. Thus, we can maintain that the frequency range of 0 – 0.7 Hz is not informative one for reflecting the influence of proprioception on equilibrium control (Thurner et al., 2000). Whereas the biggest number of statistically significant equilibrium values is noticeable at frequency range of 0.7 – 1 Hz. Thus, the frequency range of 0.7 – 1 Hz reflects the equilibrium dependence on foot stance and related to it proprioception most informatively. This fact has been confirmed during the research conducted by Thurner et al. (2000).

According to Robinovitch et al. (2002), Nigg et al. (2000), Latash (1998), the ankle strategy takes part in equilibrium control while standing still or with slight equilibrium disturbance. The ankle strategy causes COP movement when in side-by-side stance in sagittal direction (foot flexors and extensors), and the hip strategy causes COP movement in transversal direction. The hip strategy causes

COP movement when in tandem stance in sagittal direction, and the ankle strategy causes COP movement in transversal direction (Winter, 1995).

Thus, considering equilibrium maintenance not as an integral function of CNS and sensorymotor systems, but only in the aspect of participating strategies in its maintenance, we can notice, that the ankle strategy and the hip strategy of the sighted, legally blind and totally blind subjects swaying in transversal direction, with opened or blindfolded eyes, do not stabilize the COP as effectively as during the sway in the sagittal direction. Consequently, it can be one of the factors that causes higher equilibrium values when in tandem stance.

4.3. The relationship among the simple reaction and the degree of visual impairment

The capability to respond to the surrounding signals and produce a reflex or conscious response to them has a considerable influence on the control of effective activity, body segment position, movement in space and performance of the task with its results. It is not clear at what extent the degree of visual impairment influences the reaction to the surrounding stimuli. Thus, evaluating the relation between the simple reaction and visual impairment degree, we have carried out the analysis of duration values of simple reaction to the light and sound stimuli for the sighted and legally blind subjects and for the totally blind to the sound stimuli.

The analysis of the simple reaction testing results has shown that there is a tendency to react to the light more slowly than to the sound for both the sighted and legally blind subjects.

The fact of faster reaction to the sound than to the light of legally blind subjects can be explained by the idea that a partially vision do not fully reflect only different surrounding objects, but, also, it reacts worse to light stimuli. Undoubtedly, we can make a presumption that having increased the degree of contrast and light intensity, we will obtain the faster reaction. Still, it is not likely that the duration of simple reaction to light could be shorter than that to sound.

The statements of numerous researchers on the fact that a reaction to sound is faster than that to light have been confirmed by our research as well. The sighted subjects react faster to the light stimuli than to the sound ones. This difference can be determined by light and sound signals getting to CNS. The visual signal reaches CNS in 20 – 40 ms, whereas a sound signal – in 8 – 10 ms.

The simple reaction to sound testing results has shown that the totally blind and sighted subjects react to sound stimuli in a similar way.

Kosinski (2004) maintains that the average duration of simple reaction to light comes to be approximately of 180 – 200 ms, and duration of simple reaction to sound is approximately of 140 – 160 ms. The results of our research have shown that simple reaction to light of the sighted subjects falls into the standard range (200 ms), still the legally blind subjects even by 0.1 sec exceed the maximum values of reaction to light.

Referring to the research results obtained by Ando et al. (2001) we can maintain that the legally blind subjects, because of peculiarities of their central and peripheral visual field, react more slowly to a light stimulus than the sighted subjects. As is known, a simple reaction to a stimulus that is in the central part of the visual field is faster than a simple reaction to a stimulus in the peripheral part of the visual field. During the reaction of the sighted subjects to the light, normal central vision takes part, but the central vision of legally blind is disordered.

The results of our research have shown that the simple reaction to sound of all groups is slower and exceeds the margins of reaction duration to sound, provided by other scientists. The sighted subjects exceed the a.m. margins at the least extent – only by 0.03 sec, the totally blind by – 0.04 sec, and the legally blind – 0.07 s. We presume, that duration of the reaction to sound of the sighted subjects differs from that of standard insignificantly, and this difference could be determined by the intensity of the sound signal that has been used during the testing.

We have noticed that reaction values to the light and to the sound of the sighted and legally blind subjects are related closely. It has been confirmed by Pearson correlation coefficient between average values of the duration of simple reactions to light and sound. Thus, with change in duration of the reaction to light, values of duration of reaction to sound should change analogously. This show that speed of simple reaction to light and sound may be based on the activity of the same mechanisms.

The correlation between the values of simple reaction to light and sound and degree of visual impairment confirms logical conclusions: is related more closely to the visual impairment degree than the duration of simple reaction to the sound.

4.4. Varying visual impairment degree and peculiarities of psychomotor reaction

While orientation in space, performing ordinary actions or special tasks, we react more frequently to complex stimuli than to simple ones. The psychomotor reaction testing reveals not only peculiarities of automatic reaction to a stimulus, but allows us to evaluate duration of situation perception as well. The sensory and motor components of a psychomotor reaction vary in accordance with different degree of visual impairment, i.e. with vision sensory system functioning normally and with vision disorders. To assess the vision aspect of the peculiarities of psychomotor reaction, we have been registering and analysing the latent duration of psychomotor reaction to light and sound, the movement duration and the total one. We have carried out a comparative analysis of a.m. values for subjects from every group and every group of subjects concerning reaction to different stimuli.

According to the researchers, the duration of latent period of psychomotor reaction comes to be of 220 – 400 ms. In case of our research, the duration of psychomotor reaction to light and sound of the sighted subjects and the duration of psychomotor reaction to sound of the totally blind subjects have been within limits

provided. The duration of psychomotor reaction of the legally blind subjects have slightly exceeded the standard duration value.

The results of the research have shown that the latent duration of psychomotor reaction to sound of the sighted subjects has been shorter than the latent duration of reaction to light. A normal vision level causes a thorough reaction of vision analyser to the visual signals, which mean light as well, and fast recognition of these signals and their analysis in CNS. We presume that the results obtained are paradoxical, yet, it has been proved (Kosinski, 2004), that sound signals reach CNS faster than light ones. Thus, a presumption can be made that it takes shorter to recognize a sound signal, to analyse it and to choose a response to it than to perform all processes for a light signal.

The results of movement duration of psychomotor reaction to the light and sound have been opposite to the values of the latent duration: the sighted subjects perform a ballistic movement towards a light source faster than towards a sound source.

The slower recognition of a light stimuli and selection of a response to it do not determine the total duration of the psychomotor reaction: when evaluating the total PMR duration, the sighted subjects react faster to the light stimuli. The analysis of correlation between values of psychomotor reaction to the light and to the sound of the sighted subjects has shown that the total duration of psychomotor reaction is more related to the movement duration of a ballistic movement being performed than to the latent duration. Thus, we can make a presumption that the sighted subjects are more adjusted to response to visual stimuli than to audible ones, and the motor components of psychomotor reaction more influence the total duration of reaction than sensory ones.

The latent durations of psychomotor reactions to the light and to the sound of the legally blind subjects do not differ. Thus, these subjects recognize and percept equally well both light and sound stimuli. The results of our research allow us to presume that the access speed to CNS of light and sound signals does not matter for the legally blind subjects because of possible peculiarities, occurring with vision disorders, of neurophysiological mechanisms. Consequently, we could not apply to these subjects the statements by Kosinski (2004) on the access speed of light and sound signals to CNS. The movement being performed by the legally blind subjects during the psychomotor reaction to the light has been faster than that during reaction to the sound. Consequently, these subjects detect a visual stimulus faster than an audible one. Also, the total duration of psychomotor reaction to the light is shorter than the total duration of psychomotor reaction to the sound. Moreover, the correlation show that the total duration of psychomotor reaction to the sound is strongly related to the perception of a sound signal. We can make a presumption that visual sensory information predominant in psychomotor reaction control of legally blind adolescents, and localization of sound stimuli and reaction to them is slowed down.

The analysis of the results of psychomotor reaction to the light of the sighted and legally blind subjects show that the sighted subjects perform

psychomotor reactions in all aspects more effectively, and both sensor and motor components of the legally blind subjects function ineffectively.

The sighted subjects perceive the signal during both the psychomotor reaction to the light and to the sound faster than reach the signal sensor, and the legally blind subjects need a longer period of time to perceive a light signal than to reach a signal sensor. The totally blind subjects, as well as the sighted, perceive a sound signal faster than reach the sensor.

The correlation between psychomotor reaction values of totally blind subjects show that the total duration of the reaction of totally blind depends directly on the duration of a ballistic movement. Consequently, we presume that the speed of psychomotor reaction of the blind is determined by the motor components.

The analysis of values of psychomotor reaction to the sound between different groups of subjects has shown that the sighted subjects recognize the sound signal, perceive it and choose the response to it faster than the legally blind or totally blind subjects. The analogous tendency is observed when analysing the values of total duration of a psychomotor reaction to the sound. The average values of the latent and total duration of totally blind subjects show that these subjects response faster to the sound signal than those who are legally blind. All a. m. statements allow us to maintain that sensory and motor components of psychomotor reaction of the totally blind regardless of absence of vision and nonparticipating during localization of a sound signal sensor, function more effectively than the sensory and motor components of legally blind subjects.

When comparing the values of psychomotor reaction to the light of the sighted subjects and the values of psychomotor reaction to the sound of totally blind subjects, we have noticed that the sighted subjects recognize and perceive the light signals at the same speed as the blind recognize and perceive the sound signals, still the blind more slowly perform ballistic movements. According to Latash (1998) due to the vision, ballistic movements are being corrected during psychomotor reaction tasks, Nigg et al. (2000) maintain that movement accuracy and functional capabilities of vision system distinguish themselves on strong correlation. Proteau (2002) maintains that the action being performed becomes more precise when the subject can see the limb performing the movement. Consequently, we can maintain that the sensory components of psychomotor reaction of the blind function analogously to the sensory components of the sighted, and the longer ballistic movement may be related to the more complex localization of a sound stimulus and nonparticipating of vision during control of the limb movement. The sighted subjects perform ballistic movements faster, as visual sensory system takes part in movement control effectively.

The correlation between total duration of psychomotor reaction to light and sound and degree of visual impairment indicate that the visual impairment degree is more related to the psychomotor reaction to light. Such dependence is caused by the functional capabilities, which participate during psychomotor reaction to sound only partially, i.e. only during the movement.

During the research we have verified the statement whether the subjects from all groups response better to the light and sound sensors being in front of the subjects than to the lateral ones. The analysis of sensor position aspect of the results of psychomotor reaction to light and sound has shown that the reaction durations of the sighted and the totally blind subjects do not depend on the position of the signal sensor. However, the legally blind subjects response faster to the light and sound signals being emitted from the sensors in front of them. Also, the legally blind subjects touch faster the a.m. sensors.

We presume that we, referring to the signal sensor aspect of psychomotor reaction peculiarities of the legally blind subjects, are not able to make a decision on peripheral vision participation in the process of reaction. During the research we have evaluated the reaction to the sensors at the horizontal, yet, the limits of visual field are known as horizontal and vertical ones (Daktaravičienė et al., 1992). Summarizing the results of the research on simple and psychomotor reactions, we are able to maintain that reaction values of the sighted subjects do not depend on the type of signal, its position or complexity, and they are in all aspects better than corresponding values of the legally blind subjects, and reaction of the legally blind subjects is the slowest. The survey conducted by Pietrini et al. (2004) has confirmed that visual and tactile information inputs of both legally blind and sighted humans are processed by the same CNS structures. The reaction values of the blind and the sighted subjects, which do not differ significantly, allow us to think that compensatory mechanisms participate in the control of sensory and motor components of reaction that help to approach the standard values of reaction.

V. CONCLUSIONS

1. The role of visual sensory information input into equilibrium control of the sighted subjects is essential, as the results of equilibrium values show a tendency to increase when eyes are blindfolded, and proprioception and vestibular information do not compensate lack of visual information thoroughly.
2. During equilibrium control of the legally blind subjects, any sensory system presents itself as a predominant one, the equilibrium values do not depend on vision during static equilibrium maintenance, and proprioception also vestibular information do not compensate impaired vision thoroughly.
3. During equilibrium control of the blind, the proprioception and vestibular information inputs are absolutely predominant, and the activity of these sensory systems compensate the lack of visual information, consequently, the blind maintain the equilibrium better than the sighted subjects with blindfolded eyes.
4. The normal vision causes the fast simple and psychomotor reactions to the light and sound stimuli, as duration of psychomotor reaction of the sighted subjects is the shortest in comparison to that of legally and totally blind subjects.
5. During psychomotor reaction control of the legally blind adolescents, a visual information input predominate, the localization of sound stimuli and response to them are slowed down, and the sensory and motor components of reaction function ineffectively.
6. The sensory components of psychomotor reaction of the blind function analogously to the sensory components of the sighted adolescents, compensatory mechanisms, which help to approach the standard values of reaction.
7. The visual impairment degree influences the duration of simple and psychomotor reactions to the light stimuli more than duration of simple and psychomotor reaction to the sound, and it affects equilibrium values when vision participates during control of static equilibrium.

REZIUMĖ

Temos aktualumas ir naujumas. Pusiausvyra padeda išlaikyti vertikalią pozą nejudant arba atliekant sudėtingas judėjimo užduotis. Moksliniai tyrimai rodo, kad pusiausvyros stabilumas paremtas kūno masės centro padėties kontrole (El – Kashlan et al., 1998). Vertikalios pozos išlaikymui reikia regos, vestibulinio aparato labirinto, propriocepcijos ir padų mechanoreceptorių informacijos integravimo (Jeka et al., 1998; Yasuda et al., 1999).

Aktyvios veiklos, kūno segmentų padėties ir judėjimo erdvėje kontrolės efektyvumui, užduoties atlikimui ir rezultatui reikšmingą įtaką turi geba reaguoti į aplinkos dirgiklius bei inicijuoti refleksinį arba sąmoningą atsaką į juos. Ypač svarbus psichomotorinės reakcijos laikas, charakterizuojantis reakciją į sudėtingą signalą ir atspindintis ne tik latentinį ir judesio laiką, bet ir leidžiantis įvertinti situacijos suvokimo trukmę.

Optimali regos ir kitų somatosensorinių sistemų sąveika garantuoja žmogaus kūno segmentų stabilumo ir padėties kitimo kontrolę. Daugelio mokslininkų teigimu regimosios informacijos stoka sukelia pusiausvyros, kūno segmentų padėties reguliavimo, atsako į aplinkos dirgiklius pokyčius (Nougier, 1998; Bronstein ir Guerraz, 1999; Kristinsdottir et al., 2001). Vertinant reakcijos į įvairius šviesos bei garso dirgiklius pokyčius ir priklausomybę nuo tam tikrų faktorių, dažniausiai atsižvelgiama tik į tiriamųjų amžių, lytį, signalo intensyvumą, rūšį, išmokimą, CNS būklę bei regimojo signalo projekcijos vietą tinklainėje (Jevas ir Yan, 2001; Redfern et al., 2002; Ando et al., 2002; Kosinski, 2004).

Dėl regimosios informacijos svarbos pusiausvyros kontrolei abejonių nekyla. Itin daug tyrimų atlikta, siekiant išsiaiškinti regimosios informacijos įtaką kūno padėčiai arba kitų sensorinių sistemų veiklai (Collins ir De Luca, 1995; Ishida et al., 1997; Jeka et al., 1998; Bardy et al., 1999; Bronstein ir Guerraz, 1999; Ferdjallah et al., 1999; Golomer et al., 1999; Guerraz et al., 2000; Guerraz et al., 2001; Kristinsdottir et al., 2001; Hafstrom et al., 2002; Brooke-Wavell et al., 2002). Visuose analizuotuose literatūros šaltiniuose nagrinėjama mokslinė problema tik esant arba eliminavus regimąją informaciją, taip pat pusiausvyros ir reakcijos priklausomybė nuo regos apskritai, tačiau nėra aišku, kokią įtaką minėtiems pokyčiams turi regos lygis, regos sutrikimas, o taip pat kitų sensorinių sistemų veikla, pusiausvyros ir reakcijos procesuose regai nedalyvaujant.

Technologijų progreso dėka prieš laiką gimstančių naujagimių bei įvairias CNS bei regos analizatoriaus traumas patyrusių vaikų išgyvenamumas tampa įmanomas. Lietuvoje ekstremaliai mažo kūno svorio naujagimių (<1000 g) išgyvenamumas padidėjo nuo 12 % 1993 m. iki ~53 % 2002 m., labai mažo kūno svorio naujagimių (1000–1500 g) – nuo 48,3 % 1993 m. iki 88 % (2002 m.). Šiems naujagimiams gresia didžiausias somatinių bei raidos sutrikimų pavojus, kuris gali nulemti negalę. 40,21 % labai mažo gimimo svorio naujagimių serga neišnešiotų

naujų gimimų retinopatija, kuri lemia regėjimo aštrumo sutrikimus (Jurgaitienė, 2004).

Aklieji turi mažesnes galimybes vystyti savo psichomotorines funkcijas. Įrodyta, kad aklieji vaikai pradeda atlikti aktyvius tikslingus judesius tik tada, kai pradedamos suvokti garsinės komandos, kurios aktyvuoja jų judėjimą (Fraiberg, 1977; Ribadi et al., 1987). Tai ypač trikdo sutrikusios regos vaikų psichomotorinę raidą. Tuo tarpu statinė pusiausvyra yra vienas iš esminių sklandžios motorinės raidos elementų (Geuze, 2003). Todėl svarbu išsiaiškinti tokių reikšmingų judėjimo komponentų, kaip pusiausvyra ir reakcija priklausomybę nuo regos sutrikimo.

Lietuvoje ir pasaulyje mokslinių straipsnių, nagrinėjančių sutrikusios regos asmenų pusiausvyros, psichomotorinės reakcijos ypatumus aptikome vos keletą (Fraiberg, 1977; Bernard, 1979; Ribadi et al., 1987; Burton, 1992; Guerraz et al., 2000; Puišienė, 2000; Lee ir Scudds, 2003; Pietrini et al., 2004). Tiek pusiausvyra, tiek paprastoji reakcija buvo vertinama klinikinių ir Eurofito testų pagalba. Nė vienu atveju nebuvo tiriama pusiausvyros ir psichomotorinės reakcijos dydžiai instrumentiniais laboratoriniais tyrimo metodais, taip pat nebuvo atliktas tokių tyrimų rezultatų kiekybinis vertinimas.

Iki šiol nėra žinoma, kada pusiausvyros ir atsako į aplinkos dirgiklius kontrolė yra efektyvesnė: ar esant nevisavertei regimajai informacijai, ar visiškam aklumui. Taip pat neaišku, ar egzistuoja priklausomybė tarp regos sutrikimo laipsnio ir pusiausvyros bei psichomotorinės reakcijos dydžių.

Tyrimo tikslas: ištirti, kokią įtaką pusiausvyrai, paprastajai bei psichomotorinei reakcijai turi regos lygis bei nustatyti galimą kompensacinių vestibulinės ir propriocepinės sensorinių sistemų reakcijų pasireiškimą sutrikus regai.

Tyrimo uždaviniai:

1. Nustatyti regėjimo sutrikimų neturinčių, regėjimo likutį turinčių paauglių statinės pusiausvyros dydžių ypatumus dalyvaujant regai ir eliminavus regimąją informaciją ir aklųjų statinės pusiausvyros ypatumus.
2. Nustatyti regėjimo sutrikimų neturinčių, regėjimo likutį turinčių paauglių paprastosios bei psichomotorinės reakcijos į šviesą ir garsą ir aklųjų paprastosios bei psichomotorinės reakcijos į garsą dydžius.
3. Palyginti regėjimo sutrikimų neturinčių, regėjimo likutį turinčių ir aklų paauglių pusiausvyros, paprastosios ir psichomotorinės reakcijos dydžius.
4. Nustatyti regos lygio ir pusiausvyros, paprastosios bei psichomotorinės reakcijos tarpusavio ryšį, o taip pat kompensacinių vestibulinės ir propriocepinės sensorinių sistemų reakcijų pasireiškimą.

Tyrimo hipotezė:

Pusiausvyros, paprastosios ir psichomotorinės reakcijos dydžiai priklauso nuo regos lygio ir regimoji informacija lemia geresnius pusiausvyros, paprastosios ir psichomotorinės reakcijos dydžius, o regai sutrikus pasireiškia kompensacinės vestibulinės ir propriocepinės sensorinių sistemų reakcijos.

Tyrimė savanoriškai dalyvavo 45 **tiriamieji**. Siekiant iširti regos lygio įtaką pusiausvyrai, paprastajai ir psichomotorinei reakcijai, tyrimui buvo pasirinkti regėjimo sutrikimų neturintys, regėjimo likutį turintys ir visiškai akli tiriamieji. Tiriamieji buvo suskirstyti į grupes pagal regos lygius (Gudonis, 1998).

Pusiausvyros ir regos lygio sąsajai iširti buvo pasirinktas statinės posturografijos (arba stabilografijos) metodas (Goebel ir Paige, 1990; Baloh et al., 1998; Duarte et al., 2000; Стабилография, 2000; Duarte ir Zatsiorsky, 2002).

Paprastosios reakcijos tyrimui naudojome elektromiorefleksometrą, kurį sudaro šviesos arba garso signalų generavimo įrenginys, atsako įrenginys ir duomenų registravimo blokas.

Psichomotorinės reakcijos tyrimui naudojome jėgos plokštę, baltos šviesos ir garso daviklius – jutiklius, garso ir šviesos signalų generavimo įrenginį bei kompiuterinę įrangą jėgos plokštės ir daviklių – jutiklių signalų registravimui bei analizei.

Išvados:

1. Regėjimo sutrikimų neturinčių tiriamųjų regos sensorinė informacija pusiausvyros kontrolėje yra esminė, kadangi visų pusiausvyros dydžių rezultatuose pastebima verčių didėjimo tendencija pritaikius regos okliuziją, o propriocepcija ir vestibulinė informacija nevysiškai kompensuoja regos informacijos trūkumą.
2. Regėjimo likutį turinčių tiriamųjų pusiausvyros kontrolėje nėra dominuojančios sensorinės sistemos, pusiausvyros dydžiai nepriklauso nuo regos dalyvavimo statinės pusiausvyros išlaikyme, o propriocepinė ir vestibulinė informacija regos sutrikimo pilnai nekompensuoja.
3. Aklių statinės pusiausvyros kontrolėje visiška dominantė tenka propriocepijai ir vestibulinei informacijai, o šių sensorinių sistemų veikla sėkmingai kompensuoja regos informacijos trūkumą, todėl aklieji pusiausvyrą išlaiko geriau nei regėjimo sutrikimų neturintys tiriamieji, pritaikius regos okliuziją.
4. Normalus regėjimo lygis sąlygoja greitą paprastąją ir psichomotorinę reakciją į šviesos ir garso dirgiklius, kadangi regėjimo sutrikimų neturinčių tiriamųjų paprastosios ir psichomotorinės reakcijos laikas yra trumpiausias lyginant su regėjimo likutį turinčių ir aklių tiriamųjų reakcijos laiku.

5. Regėjimo likutį turinčių paauglių psichomotorinių reakcijų kontrolėje vyrauja regos sensorinė informacija, garso dirgiklių lokalizacija ir reagavimas į juos yra sulėtėjęs, o sensoriniai bei motoriniai reakcijos komponentai funkcionuoja neefektyviai.
6. Aklųjų psichomotorinės reakcijos sensoriniai komponentai funkcionuoja analogiškai regėjimo sutrikimų neturinčių paauglių sensoriniams komponentams, aklųjų sensorinių bei motorinių reakcijos komponentų kontrolėje dalyvauja kompensaciniai mechanizmai, priartinantys reakcijos dydžius prie normos.
7. Regos lygis įtakoja paprastosios ir psichomotorinės reakcijos į šviesos dirgiklį laiką labiau nei paprastosios ir psichomotorinės reakcijos į garsą laiką, o taip pat veikia pusiausvyros dydžius, kai statinės pusiausvyros kontrolėje dalyvauja rega.

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ABOUT AUTHOR

Education

- 1994 – 1998 Undergraduate studies in Adapted physical activity at Lithuanian Academy of Physical Education. Bachelor's degree.
- 1998 – 2000 Master studies in Sports physiology at Lithuanian Academy of Physical Education. Master's degree in Biology.
- 2000 – 2002 Studies in Pedagogics for Low vision at Siauliai University Continuing Studies Institute. Bachelor's degree.
- 2000 – 2005 PhD studies in Biology Lithuanian Academy of Physical Education.

Practical experience

- 1997 – 2004 Teacher of Therapeutic physical culture – Physiotherapist in Kaunas Boarding School for Low vision children.
- 2002 – 2004 The head of Social Education Department in Kaunas Boarding School for Low vision children.
- 2004 – 2005 Physiotherapist in Virsuziglis Pension and Sanatorium.
- 2005 – present Physiotherapist in Kaunas Nursing Hospital.
- 2005 – present Teaching assistant in Physiotherapy and Sports medicine Department, Lithuanian Academy of Physical Education.