The influence of the degree of visual impairment on psychomotor reaction and equilibrium maintenance of adolescents

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Summary. The changes in such human motor performance processes as stability maintenance, production of a response to the environment may be observed if loss of vision or any vision impairment appears. A total of 45 sighted, legally or totally blind subjects volunteered in the study. The influence of the degree of visual impairment on simple, psychomotor reaction and equilibrium parameters was assessed. Reaction and equilibrium dependence on the degree of visual impairment and the possible existence of compensatory motor reactions of visually impaired adolescents were evaluated in the study.

Results allowed thinking that insufficient visual information hampers motor performance and maybe the development of the compensatory motor reactions of the legally blind. Approximate values of the reaction parameters of the sighted with open eyes and the totally blind subjects allow one to predicate that the compensatory motor reactions of the blind probably exist. Testing results of the sighted and totally blind subjects are not equal; therefore, we can suppose that intensified tactile or vestibular function cannot absolutely replace the presence of normal vision in motor control.

Introduction
The human body is kept in equilibrium by a sophisticated process including the processing of three main types of information: visual, vestibular, and proprioceptive. The result of this process is constant movement of the human foot center of pressure (COP) (1). The optimum interaction between visual and somatosensory impulses guarantees control of orientation and stability of the body segments. The stability and control of body segment location, also the response to environment, are disconcerted if lack of visual information appears (2). Visual information is very important for control of equilibrium and estimation of the motion speed of the objects and body segments, also for the time and accuracy of the psychomotor reaction.

Reaction time is an important component of motor performance. Simple reaction time was investigated in most cases (3, 4). Psychomotor reaction (PMR) time is more important because it characterizes reaction to a complex stimulus and includes not only latent time of reaction, but also the time of perception and the time of the movement performance.

The changes in such human motor performance processes as maintenance of stability, producing of the response to the environment may be observed if loss of vision or any vision impairment appears. It is questionable, what effect does the degree of visual impairment have on motor performance? Is movement performed better without vision or with insufficient visual information? Therefore, the purpose of the study was to assess the dependence of psychomotor reaction and equilibrium maintenance on the degree of visual impairment.

Material and methods
Subjects
The study was approved by Lithuanian Bioethics Committee. A total of 45 subjects volunteered in the study. The visually impaired adolescents were recruited from among general volunteers of the Kaunas Boarding School for the Visually Impaired, in Kaunas, Lithuania. The sighted adolescents were recruited from a comprehensive school in Kaunas, Lithuania. All of the adolescents were at a normal level of schooling. None of the subjects was going in for sports or had any health disorders. The groups were formed according to visual acuity. Twenty sighted, with no visual impairment (group S; visual acuity from 6/7.5 to 6/6; 10 boys and 10 girls), 13 legally blind (group...
L, visual acuity from 6/600 to 6/200; 7 boys and 6 girls) and 12 totally blind (group B; visual acuity 0; 6 boys and 6 girls) pupils participated in the study. Anamnesis showed that central vision, which is stimulated by an object, imaged on the fovea centralis of group L was impaired. The subjects’ ages vary from 11 to 15 years. These ages were chosen because of the existence of a critical period of around 7 to 8 years of age in the development of sensory-motor processes and postural control (2).

Measures and procedures

The parameters of simple reaction, psychomotor reaction and equilibrium were investigated in the study. This investigation was performed to define the peculiarities and influence of the degree of visual impairment on these processes.

Simple reaction time to sound and light signals was measured with an electromyoreflexometer, EMP-1. This device is used for determining parameters of reaction in neurology, neurosurgery and psychiatry.

The sighted, legally blind and totally blind participants had to switch off the signal by touching the sensor as quickly as possible after the signal was generated. The sighted subjects reacted to the light signal (10 trials), to the sound signal with open eyes (10 trials) and to the sound signal blindfolded (10 trials). The legally blind subjects reacted to the light (10 trials) and sound (10 trials) signals with open eyes. The totally blind adolescents reacted to the sound signals (10 trials). The data of the reaction to the stimulus of the each group were collected and grouped considering the type of signal. The average reaction time (t) of each group was used for the analysis.

The testing of psychomotor reaction was performed using the PMR testing system (created and approved at the Lithuanian Academy of Physical Education). This system tested the PMR time and other parameters of human motor function (5, 6). The testing system consists of the serial produced force platform MA-1 (hard metallic surface, 750×750 mm), 6 light or sound emitting sensor devices located on a half-circle shaped frame surrounding the platform, equipment emitting light or sound signals, software controlling light or sound signals and analyzing recorded signals (Fig. 1).

The measurement was performed in a quiet room. The subjects were required to stand in the center of the force platform during the PMR testing. The subjects were instructed to switch off light or sound signals as quickly as possible by touching the sensor after the light or sound signal was generated. The sequence of switching on the 6 sensors was random. The next sensor switched on 2 to 5 seconds after previous one had been touched and the light or sound signal was terminated.

Since the subjects were standing on the force platform they caused the changes of the ground reaction force by accomplishing the movement of reaching-touching the sensors. The changes of the ground reaction force and termination of the signals were automatically registered. The latent PMR time (t Lat) is between the moment of the signal generation and the movement (Fig. 2). The total PMR time (t Total) is the time from the beginning of the signal until interruption of the signal. The time of the movement (t Mov) is the latent time subtracted from the total PMR time (t Mov = t Total - t Lat). As in the simple reaction, testing data of the PMR of each group were collected and grouped considering the type of signal. The averages of the t Up, t Lat, t Mov of each group were used for the analysis.

The equilibrium testing was performed using static posturography method, which evaluates somatosensory and visual influences on posture and equilibrium (7). The serial produced force platform MA-1 and software analyzing recorded signals were used in the equilibrium testing. The sway of the foot center of pressure (COP) in x (sagittal direction) and y (transversal direction) was registered (Fig. 3). The discretization of the signal was 10 ms. The duration of the posturogram record was 60 seconds (7).

*Fig. 1. The layout of the gear for registering psychomotor reaction parameters*

1, 2, 3, 4, 5, 6 – light or sound emitting sensors.
Fig. 2. The determination of psychomotor reaction components

$t_{lat}$ – the time between the beginning of the signal and the moment when the force curve begins to curve from isoline; $t_{off}$ – from the beginning of the signal until interruption of the signal; $t_{mov}$ – the time of the movement.

Fig. 3. The sway of the foot center of pressure (COP) in $x$ (sagittal direction) and $y$ (transversal direction)

The posturogram (curves of the COP sway) was registered while participants stood still in two postures with open eyes and blindfolded in the center of the force platform. The first posture is legs closed together with arms at the sides, the second – legs closed together with arms reaching forward.

The length of the COP pathway ($s$) and the length of COP dislocation in $x$ ($x$) and $y$ ($y$) directions were estimated. The data of each group of the subjects were collected and the average of each parameter was used for the analysis.

The sighted and legally blind subjects were blindfolded in order to define the importance of vision for maintenance of equilibrium. No facts supporting that blindfolding may impact static equilibrium of the blind were found. Therefore, the totally blind subjects were not blindfolded.

Data and statistical analysis

One factorial analysis of variance (ANOVA) with post hoc Tukey’s honestly significant difference (HSD) test was used to determine significant differences between each measured parameter of all groups. Dependent variables were $t$, $t_{lat}$, $t_{off}$, $t_{mov}$, $s$, $x$, $y$. Statistical significance was set at $p<0.05$. The statistical analysis was performed with SPSS 11.0 software.
Results
The results of the simple reaction and psychomotor reaction testing are summarized in Fig. 4, 5 and 6. The time of the simple reaction \(t\) and psychomotor reaction \(t_{\text{mov}}\) to the light signal (Fig. 4) of the adolescents without visual impairment was significantly shorter than to the sound signal, \(t\), \(F(1, 39) = 1.89, p<0.05, t_{\text{off}}\), \(F(1, 43) = 45.87, p<0.05\) (Fig. 5). The time of simple reaction and psychomotor reaction to the light signal of the sighted adolescents appeared significantly shorter than the simple reaction time and components of psychomotor reaction time of the legally blind adolescents, \(t\), \(F(1, 41) = 1.76, p<0.05, t_{\text{off}}, F(1, 41) = 11.53, p<0.05, t_{\text{mov}}, F(1, 41) = 10.28, p<0.05, t_{\text{mov}}\), \(F(1, 41) = 3.79, p<0.05\) (Fig. 4).

The time of psychomotor reaction to the sound signal of the sighted subjects with open eyes appeared significantly shorter than while blindfolded, \(t_{\text{off}}\), \(F(1, 41) = 2.60, p<0.05\) (Fig. 5). Also the adolescents without visual impairment performed movements qui-

Fig. 4. The time of the simple and psychomotor reaction to the light
\(t\) – simple reaction time; \(t_{\text{lat}}\) – latent psychomotor reaction time; \(t_{\text{mov}}\) – psychomotor reaction movement time \((t_{\text{mov}} = t_{\text{off}} - t_{\text{lat}})\); \(t_{\text{off}}\) – total psychomotor reaction time; S – sighted adolescents; L – legally blind adolescents.

Fig. 5. The time of the simple and psychomotor reaction to sound of the sighted adolescents with open eyes and blindfolded
\(t\) – simple reaction time; \(t_{\text{lat}}\) – latent psychomotor reaction time; \(t_{\text{mov}}\) – psychomotor reaction movement time \((t_{\text{mov}} = t_{\text{off}} - t_{\text{lat}})\); \(t_{\text{off}}\) – total psychomotor reaction time.
Fig. 6. The time of the simple and psychomotor reaction to sound with open eyes

$t$ – simple reaction time; $t_{lat}$ – latent psychomotor reaction time; $t_{mov}$ – psychomotor reaction movement time ($t_{mov} = t_{off} - t_{on}$); $t_{off}$ – total psychomotor reaction time; S – sighted adolescents; L – legally blind adolescents; B – totally blind adolescents.

cicker with open eyes than blindfolded, $t_{mov}, F(1, 41)=2.69, p<0.05$. The latent time of the psychomotor reaction to the sound of the sighted pupils did not differ significantly when they reacted with opened eyes and blindfolded.

The time of simple reaction and psychomotor reaction of the legally blind subjects showed that the legally blind react to sound with opened eyes slower than the blind, $t, F(1, 40)=1.63, p<0.05$, sighted blindfolded, $t, F(1, 40)=1.44, p<0.05$ (Fig. 6).

The simple reaction time to sound of the sighted is shorter than reaction time of the totally blind subjects, sighted with open eyes, $t, F(1, 42)=1.44, p<0.05$, sighted blindfolded, $t, F(1, 42)=1.48, p<0.05$ (Fig. 6).

Comparing the results of psychomotor reaction of the sighted blindfolded and the totally blind we found that the totally blind subjects react to the sound quicker than the sighted, $t_{off}, F(1, 43)=1.69, p<0.05$, $t_{mov}, F(1, 43)=2.40, p<0.05$ (Fig. 5, 6). The difference between time of the psychomotor reaction ($t_{on}$) of the sighted with open eyes and the totally blind appeared insignificant; therefore, the psychomotor reaction time is similar (Fig. 6).

The results of the equilibrium stability testing are summarized in Fig. 7, 8 and 9.

The highest and significant differences between stability parameters under conditions with open eyes and blindfolded were of the subjects without visual impairment in the 1st posture. The values of all recorded posturogram parameters of the sighted were significantly higher while standing with closed than opened eyes. COP dislocation in x direction ($x$) and y direction ($y$) also the length of the COP pathway ($s$) increased, $s, F(3, 18)=5.61, p<0.05, x, F(3, 18)=7.44, p<0.05, y, F(3, 18)=4.59, p<0.05$ (Fig. 7A, 8).

The differences between the values of stability parameters under conditions with open eyes and blindfolded of the legally blind were statistically insignificant in the first posture (Fig. 7A, 8).

Results showed that the sighted adolescents with open eyes evidently maintain equilibrium better than legally blind and lateral sway of the legally blind appears significantly bigger compared to the sighted, $s, F(3, 14)=3.89, p<0.05, y, F(3, 14)=4.27, p<0.05$ (Fig. 7A, 8B).

The values of the stability parameters of the legally blind with opened eyes and blindfolded were approximate to respective parameters’ values of the blindfolded sighted adolescents. The values of the posturogram parameters of the totally blind subjects were approximate to parameters of sighted pupils with open eyes (Fig. 7B, 8, 9).

The results of the equilibrium testing of the totally blind adolescents showed that totally blind subjects and sighted subjects have similar ability to maintain stability. Furthermore, the totally blind adolescents

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**Fig. 7. The length of the COP pathway**

A – first posture; B – second posture; s – COP pathway; S – sighted adolescents; L – legally blind adolescents; B – totally blind adolescents.

**Fig. 8. The COP dislocation in the first posture**

A – x (sagittal) direction; B – y (transversal) direction; S – sighted adolescents; L – legally blind adolescents; B – totally blind adolescents.

**Fig. 9. The COP dislocation in the second posture**

A – x (sagittal) direction; B – y (transversal) direction; S – sighted adolescents; L – legally blind adolescents; B – totally blind adolescents.

are more stable compared to blindfolded sighted subjects, in the first posture, s, $F(3, 18) = 5.18$, $p<0.05$, in the second posture, s, $F(3, 18) = 8.62$, $p<0.05$ (Fig. 7). The equilibrium stability parameters of the totally blind subjects were worse than stability parameters of the sighted with open eyes in the first posture, s, $F(3, 18) = 9.42$, $p<0.05$ (Fig. 7), differences between groups in the second posture are insignificant.

Totally blind adolescents maintain equilibrium better than blindfolded legally blind subjects, first
posture, s, $F(3, 14)=4.36$, $p<0.05$, second posture, s, $F(3, 14)=7.24$, $p<0.05$ (Fig. 7).

The amplitude of the COP sway of the sighted adolescents with open eyes in the second posture was insignificantly greater than in the first posture. The COP moved up and forward in the second posture sagittal direction and, therefore, changed the stability coefficient and angle, and postural stability decreased.

The parameters of COP sway in the second posture of the sighted under blindfold were similar to those of the first posture. The equilibrium stability parameters of the blindfolded sighted subjects were lower than with open eyes, second posture, s, $F(3, 18)=5.92$, $p<0.05$. The changes of the COP under blindfold increased insignificantly in x direction.

The differences between stability parameters of the legally blind subjects with open eyes and blindfolded were insignificant in the second posture (Fig. 9).

The posturography results of the legally blind and sighted adolescents under blindfold in the second posture did not differ in essence. The values of the posturogram parameters of the totally blind and sighted subjects with open eyes did not differ significantly.

The legally blind adolescents maintained equilibrium more poorly than adolescents without visual impairment in the second posture with open eyes, s, $F(3, 14)=3.78$, $p<0.05$ (Fig. 7B).

**Discussion**

The purpose of our study was to evaluate the dependence of the psychomotor reaction and equilibrium on the degree of visual impairment. We predicted that psychomotor reaction and performance of the movements and equilibrium maintenance are directly dependent on the degree of visual impairment and the lowest parameters would appear in the totally blind subjects.

We found that all parameters of the simple and psychomotor reaction of the legally blind appeared worse than of the totally blind subjects. The comparison of the simple reaction and psychomotor reaction testing results of the totally and legally blind adolescents implies that there is a possibility of compensatory reactions in motor control of the blind. The legally blind used insufficient visual information, and motor reactions appeared slow. Thus, such results allow one to think that insufficient visual information hampers motor performance and maybe the development of the compensatory motor reactions of the legally blind.

The analysis of the psychomotor reaction parameters of the sighted blindfolded and the totally blind participants showed that the totally blind adolescents have certain superiority in motor control. Approximate values of the reaction parameters of the sighted with open eyes and the totally blind subjects allow one to predicate that the compensatory motor reactions of the blind probably exist and the sighted are not used to acting without vision; visual information is predominant in motor control of the sighted (8). However, the testing results of the sighted and totally blind subjects are not equal; therefore, we can suppose that intensified tactile or vestibular function cannot absolutely replace the presence of normal vision in motor control.

The study showed that legally blind subjects maintain equilibrium more poorly than totally blind subjects and subjects with no visual impairment. It implied that equilibrium maintenance of the legally blind was poor because of the deficit of visual information in postural control. Furthermore, the results enable one to think that poor information about the environment, location and orientation of the body segments is received mostly by impaired vision and compensatory proprioceptive reactions may be developed insufficiently.

Many researchers (9) studying the influence of vision on the control of equilibrium assert that the greatest part of the control of maintaining vertical equilibrium falls on central vision. Central vision is efficient for controlling center of foot pressure oscillations in antero-posterior and medio-lateral directions, and visual acuity affects equilibrium control directly (2). It is maintained (9) that central vision affects the lateral sway more than peripheral vision. The central vision of group L was impaired. Therefore, significant lateral sway is noticed if impairment of central vision appears (Fig. 9B).

Totally blind pupils maintain equilibrium better than legally blind pupils with open eyes and blindfolded. This superiority may be determined by better-developed proprioceptive and vestibular reactions. The equilibrium stability parameters of the totally blind also appeared to be better than blindfolded sighted adolescents. It confirmed the possible existence of equilibrium compensatory reactions of the blind. The equilibrium stability parameters of the totally blind subjects were worse than those of the sighted with open eyes. That may depend on the fact that proprioceptive information of the blind replaces visual information, but cannot compensate for it totally.

Equilibrium maintenance of the blindfolded sighted subjects was lower than with open eyes. The slow reaction to the stimulus and slow movements while blindfolded confirmed that proprioceptive information
appeared as supplemental compared to visual information for the sighted (8, 10). Thus, the sighted adolescents with closed eyes maintain equilibrium better than the legally blind, but worse than the totally blind because visual information appears predominant in the control of equilibrium of the sighted.

The main findings of the motor components testing of the totally blind subjects implies that the lack of controlling vision impulses on posture, coordination of movement, location of the body segments or perception of movement can be compensated by intensification of the proprioception, vestibular or hearing function if loss of vision appears.

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Regos sutrikimo įtaka paauglių pusiausvyrai ir psichomotorinė reakcijai

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Raktažodžiai: regos sutrikimas, paprastoji reakcija, psichomotorinė reakcija, pusiausvyra.

Santrauka. Optimali regos ir kitų somatosensorinių sistemų sąveika užtikrina žmogaus kūno segmentų stabulumo ir padėties kitimo kontrolę. Regimosios informacijos stoka sukelia pusiausvyros, kūno segmentų padėties reguliavimo, atsako į aplinkos dirgiklius pokyčius. Tyrimo tikslas – įvertinti regos sutrikimo įtaką statinės pusiausvyros, paprastosios ir psichomotorinės reakcijos rodikliams. Tyrimo savanoriškai dalyvavo 45 tiriameji: visiškai akli tiriameji (n=12), tiriameji, kuriems išlikęs regos likutis (n=13), tiriameji, kuriems nerasta režėjimo sutrikimų (n=20). Remiantis tyrimo duomenimis, tiriamejims, kuriems išlikęs regos likutis, nepakankama regimosi informacijos trikdė kompensacinių reakcijų vystymąsi. Tiriamejų, kuriems nerasta regos sutrikimų, atmerktomis akimis ir visiškai akli tiriameji paprastosios ir psichomotorinės reakcijos rodiklių vidurkiai yra panašūs, todėl manome, jog aklių sensomotorikoje atsiranda kompensacinių reakcijos. Vis dėlto reginčių ir aklių pusiausvyros, paprastosios ir psichomotorinės reakcijos rodiklių vidurkiai nėra lygūs, todėl sprendžiame, kad kompensacinės reakcijos regimosios informacijos, kontroliuojant jėdas, visiškai pakeisti negali.

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