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Postural Reflexes in Conditions of Visual Disturbance

Posturální reflexy v podmínkách zrakové poruchy

Abstract

Introduction: Tests of balance are routine elements of neurological and otolaryngological examination. What follows is a general study of the effectiveness of balance control when visual-vestibular integrity is disturbed, conducted by means of ascertaining the influence of vertical and horizontal visual stimulation on postural reflexes as measured by craniocorpography. *Goal:* The purpose of the study was to observe the effect of visual, horizontal and vertical optokinetic and sinusoidal stimulation on postural reflexes. *Material and method:* A group of 40 healthy subjects (20 female, 20 male) aged 18–52 with no pathological otoneurologial history or signs was tested. Horizontal and vertical optokinetic and sinusoidal stimulation was administered in order to observe balance disturbances, as measured by craniocorpography in the course of a Romberg test. *Results:* It was revealed that visual stimulation (optokinetic and sinusoidal) in the horizontal plane induced stronger postural disturbances than visual stimulation in the vertical plane. Both horizontal and vertical optokinetic stimulation resulted in high longitudinal body sway. Lateral body displacement was better controlled during vertical visual disturbances. The authors observed that the differences in postural reflexes were dependent on the direction of both horizontal and vertical visual stimulation. Balance control was better when the optokinetic incitement was directed to the left and downward. Increased intensity of visual stimulus (target velocity) did not worsen balance.

Souhrn

Úvod: Testy rovnováhy jsou běžnou součástí neurologického a otorhinolaryngologického vyšetření. Cílem této studie bylo prozkoumat vliv vertikální a horizontální vizuální stimulace na posturální reflexy měřené kraniokorpografií, za účelem podrobného ověření účinnosti kontroly rovnováhy při narušení vizuálně-vestibulární integrity. *Cíl:* Cílem studie bylo zjistit vliv vizuální, horizontální a vertikální optokinetické a sinusoidální stimulace na posturální reflexy. *Metodologie:* Testována byla skupina 40 zdravých jedinců (20 žen, 20 mužů) ve věku 18–52 bez patologické otoneurologické anamnézy nebo příznaků. Za účelem zjištění poruch rovnováhy měřených kraniokorpografií během Rombergova testu byla aplikována horizontální a vertikální optokinetická a sinusoidální stimulace. *Výsledky:* Zjistili jsme, že vizuální stimulace (optokinetická a sinusodiální) v horizontální rovině vyvolaly silnější posturální poruchy než vizuální stimulace ve vertikální rovině. Jak horizontální, tak vertikální optokinetická stimulace vedla k větším longitudinálním výkyvům těla. Laterální vychýlení těla bylo lépe kontrolováno během vertikální stimulace. Autoři zjistili rozdíly v posturálních reflexech v závislosti na směru jak horizontální, tak vertikální vizuální stimulace. Kontrola rovnováhy byla lepší, byla-li optokinetická stimulace směřována doleva a dolů. Zvýšená intenzita vizuální stimulace (cílová velocita) rovnováhu nezhoršovala.

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Accepted for review: 16. 9. 2010
Accepted for print: 9. 5. 2011

Key words

postural reflexes – balance – craniocorpography – visual stimulation – otoliths

Klíčová slova

posturální reflexy – rovnováha – kraniokorpografie – vizuální stimulace – otolity

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Introduction

Tests of balance are routine elements of neurological and otolaryngological examination. The Romberg test and the Unterberger-Fukuda test (walking on the spot) are quick ways to examine the ability to maintain balance while standing and moving [1–3]. The Romberg test is not considered to be very sensitive – a little swaying is normal, but the range of body oscillations is not well-defined, and comparison of the deviations in position between the first and following examinations is difficult when the estimation is only approximate [1]. In the Unterberger-Fukuda test, a high number of inter- and intra-individual variations may be noted [4]. Among other balance assessment tools that allow differentiation of balance deficit, craniocorpography, is easy and quick, both as an ambulatory screening examination and as a component of more sophisticated vestibular research [5–7]. Adding some interesting parameters to routine analysis of the Romberg and Unterberger-Fukuda tests, craniocorpography is capable of measuring head stability (on the basis of torticollis angle) and a widened base of support while stepping (on the basis of shoulder oscillation) [8]. It can be also used for monitoring recovery and for balance training when sensory system integration is deliberately distracted, for example by additional visual stimulus [9].

It is known from Wood [10] and Dichgans et al [11] that visual optokinetic stimulation breaks up vestibulo-visual integration. The signs of travel sickness, without motion but after visual signal, were first described in 1895. Similarly, when the pseudo-Purkinje effect is provoked, real postural disturbances (apart from vegetative symptoms) may be observed. [12]. The irritation of otoliths and ocular motor signals following visual stimulation and burst neurons in the brainstem are believed to change the well-known efference copy, contributing to postural instability [12–15].

The authors of this study wished to ascertain the influence of vertical and horizontal visual stimulation on postural reflexes measured by craniocorpography, in order generally to study the effectiveness of balance control when visual-vestibular integrity is disturbed.



Fig. 1. Craniocorpography: movement detectors are fixed on the patient's shoulders and on the helmet.

The aims of the investigation were:

- To observe balance control in healthy people on the basis of craniocorpography during a static test disturbed by visual stimulation (horizontal and vertical optokinetic stimulation and sinusoidal stimulation).
- To compare the types and intensities of visual deficiency that have the greater effects on postural control, the better to facilitate the process of rehabilitation.

Material and methods

A group of 40 healthy people (20 female, 20 male) aged 18–52 with no history of otoneurological abnormalities was recruited for testing. Firstly, postural balance was observed in the whole group and measured by craniocorpography in a static Romberg test (standing erect for 60 seconds, with feet together and the arms extended straight in front) with eyes closed, and a stepping Unterberger-Fukuda test (50 steps on the spot for 60 seconds) with eyes closed and both arms stretched forward.

Craniocorpography (Craniocorpograph, Zebris Medical GmbH, Germany) allows the measurement of trunk and head oscillations and turns by means of movement detectors fixed on the pa-

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Fig. 2. Craniocorpography: Unterberger-Fukuda test.

tient's shoulders and on a helmet that is placed on the head (Fig. 1).

Craniocorpography during the static Romberg's test allows the following parameters to be evaluated: longitudinal body oscillations (cm), lateral body oscillations (cm), forehead area (cm^2) and the angular deviation of the head in relation to the trunk (°). The Unterberger-Fukuda test was analysed during craniocorpography on the basis of: the track that the subject covered from the starting point (the patient is asked to step on the spot, but walks ahead without being aware of it) (cm), lateral sway of the shoulders when stepping (higher values for this measurement often indicate a wider base of support, as in cerebellar syndrome) (cm), angular deviation in the line of stepping from the start point (°), and angular deviation of the body (°) (Fig. 2).

After these tests, the trial group was divided into two equal subgroups to observe changes in postural balance when normal testing is disturbed by visual stimulation (this part of the test appears to have applications in the rehabilitation of vertigo patients). The observations of these two subgroups allow us to compare how a person controls balance during standing and walking when the visual receptor is completely excluded from postural control (first step of the study, described above) and when the vision is active, but disturbed. The subgroups were selected to avoid any mechanism of habituation should visual stimulation be frequently repeated [16]. To check whether the subgroups were compatible, statistical evaluation of differences between them was carried by means of Student's t-test (Table 1).

The first subgroup consisted of 20 people (10 female, 10 male) aged 18–46 (mean: 32.1). Horizontal (to the left, then to the right) optokinetic and sinusoidal horizontal stimulations took place with the patient standing with the hands extended ahead and eyes open. The patient was asked to follow a moving target presented two metres in front, with both eyes. Optokinetic and sinusoidal stimulation lasted for 60 seconds at velocities of 10°/s and 20°/s for optokinetic stimulation and 20°/s during the sinusoidal.

The second subgroup consisted of 20 people (10 female, 10 male) aged 18–52 (mean: 34.2). Balance was tested during the same standing test, with the eyes open, as in the first group, but with vertical rather than horizontal stimulation for 60 seconds, upwards then downwards at rates of 10°/s and 20°/s and sinusoidal vertical stimulation at a velocity of 20°/s.

The data were compared by Student's t-test; the threshold for significance was set at <0.05.

Results

The two selected subgroups were compared in order to confirm that they were statistically identical. None of the craniocorpographical parameters either during the Romberg test or the Unterberger-Fukuda test were different (Table 1). The results of cranicorpography during static Rom-

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Table 1. Results of Romberg test and Unterberger test in terms of craniocorpography for two selected groups of healthy subjects.

Craniocorpography parameters	First group: mean value/standard deviation	Second group: mean value/standard deviation	Value of Students t-test (critical value = 0.05)
Static (Romberg's) test			
longitidinal sway (cm)	7.07/2.62	6.47/3.51	0.27
lateral sway (cm)	3.83/2.55	4.82/2.75	0.12
forehead area (cm²)	24.88/23.55	34.6/38.82	0.17
torticollis angle (°)	9.76/8.45	7.76/15.2	0.32
Stepping (Unterberger's) test			
longitudinal deviation (cm)	73.74/40.17	84.66/37.83	0.19
lateral sway (cm)	39.03/58.75	36.15/74.18	0.45
angular deviation (°)	19.78/24.14	10.27/24.32	0.11
self spin (°)	49.82/52.09	36.04/50.13	0.22

berg test on visual stimulation – horizontal and vertical – are presented in Table 2.

A comparison of the parameters derived from craniocorpography in the course of the various stimulations, optokinetic and sinusoidal, horizontal and vertical, was made. Table 3 presents the results of the Student's t-test.

Significant difficulties in balance control were clearly evident when horizontal visual disturbance was applied. Both optokinetic and sinusoidal stimulation resulted in postural instability. Balance control was worst in the frontal plane. Lateral body sway was high for every type of disturbance: slow and fast optokinesis, both to the right and to the left and during sinusoidal impulse. Longitudinal sway and forehead area were disturbed

Table 2. Results of craniocorpography during static test with eyes open and visual disturbance induced by horizontal and vertical optokinetic and sinusoidal stimulation.

Type of stimulation	Craniocorpography parameters: mean value/standard deviation			
	Longitudinal sway (cm)	Lateral sway (cm)	Forehead area (cm²)	Torticollis angle (°)
Horizontal stimulation:				
10° to the left	9.49/7.65	6.10/4.04	76.30/127.99	8.29/6.15
20° to the left	12.84/12.45	8.05/7.12	50.96/36.35	8.48/6.33
10° to the right	11.25/7.29	6.74/2.84	79.41/74.50	7.94/5.12
20° to the right	10.33/7.08	6.98/3.63	62.48/49.37	7.94/5.11
20° sinusoidal	9.47/7.35	6.72/2.77	75.45/98.04	6.91/5.00
Vertical stimulation:				
10° upward	8.68/4.06	6.12/4.09	61.62/86.24	7.13/4.75
20° upward	10.37/5.98	5.51/2.51	59.24/56.66	4.54/4.42
10° downward	8.20/3.60	5.85/3.07	43.35/32.95	5.25/7.06
20° downward	8.66/6.88	4.94/1.72	35.01/25.28	4.38/6.33
20° sinusoidal	7.91/2.62	5.62/2.15	39.71/19.69	7.01/9.80

Table 3. Comparison of craniocorpographical parameters during Romberg's test when eyes are closed and under optokinetic and sinusoidal stimulation (significant differences in grey).

Tests compared	Results of Student's t-test (critical value = 0.05)			
	Longitudinal sway	Lateral sway	Forehead area	Torticollis angle
eyes closed – opk left 10°/s	0.1	0.02	0.05	0.27
eyes closed – opk left 20°/s	0	0.01	0.01	0.3
eyes closed – opk right 10°/s	0.01	0	0	0.21
eyes closed – opk right 20°/s	0.03	0	0	0.21
eyes closed – sinus. horizontal 20°/s	0.09	0	0.02	0.1
eyes closed – opk up 20°/s	0.01	0.2	0.06	0.23
eyes closed – opk down 10°/s	0.07	0.13	0.22	0.29
eyes closed – opk down 20°/s	0.11	0.43	0.48	0.23
eyes closed – sinus. vertical 20°/s	0.07	0.16	0.3	0.44

Opk right – optokinetic stimulation to the right; opk left – optokinetic stimualation to the left; sinus. – sinusoidal stimulation

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(increased) during optokinetic stimulation to the left at a velocity of 20°/s and during optokinetic stimulation to the right at both 10°/s and 20°/s velocity. Torticollis angle remained normal during each horizontal stimulation. The only effect of vertical disturbance of visual field on postural control was an increase in longitudinal sway during upward optokinetical stimulation (Table 3). Differences in body balance were not observed when stimulation strength was increased (Table 4).

Discussion

The main purpose of the study was to observe the ability to maintain balance coordination when one of the essential receptors, the visual, is excluded or its function disturbed. Craniocorpography was chosen for quantitative and qualitative balance study [5,9]. It allows description of axis, direction and intensity in balance disturbance.

Our results indicated that visual disturbances have a negative effect on postural control. This supports observations by Glasauer et al [15] that eye movements increase sway and that suppression of the ocular motor component reduces postural imbalance. Intersensory interaction with remembering the previous efference copy is one reason for balance deficit: the drive to rebuild afference control (ocular, skeletal muscles) is the key to recovering equilibrium [13,17–19]. The active involvement of gravity – the essential role of the otoliths – may play a role in correcting this linkage, as will be explained below [17].

When visual failures are present, their control is essential for postural stability. A lack of balance control was clearly observed when visual stimulation was moving horizontally. Such visual field disturbance is followed largely by greater lateral sway, independently of whether it was stimulated to the right or to the left. Lateral sway was greater during sinusoidal stimulation.

Instability in the saggital axis was also observed during horizontal visual stimulation but was particularly associated with rightwards direction of disturbance. Optokinetic nystagmus to the left normally follows optokinetic stimulation to the right with a tendency to body declination to the slow phase of nystagmus. Right-handed people with suspected greater tonus of the right-side muscles may not be able to oppose the force drawing them to the right. An increase in balance disturbances – both lateral and longitudinal sway – are consequences of such a situation.

It was very interesting that vertical visual field disturbance (optokinetic and sinusoidal) generally affects balance only weakly. Vertical stimulation is not frequent in daily life. It might therefore be suspected that visual failure in this plane would cause deeper balance discoordination than horizontal visual field movement. This was not observed in our study. The effect of developing a major sensitivity to a frequently repeated stimulation (in the horizontal plane), such as the greater sensitivity of the vestibulo-sympathetic reflex in the familiar head-down prone position (exact horizontal position of the utricular maculas), may be a possible explanation [20]. Moreover, Murofushi et al [21] suggested that the utricle is more respondent to acute perturbation than the sacculus. Taking into consideration the utricular responsibility for subjective horizontal vision, its disorientation may play a role in the resultant increase in lateral postural sway. Further, one must bear in mind not only the direct influence of retinal scanning of visual field movement but also extra-ocular (afferent and efferent) memory implies sensitivity as a forerunner of executive body sway [15].

Slight differences were presented when comparing upward and downward vertical stimulation. The balance problems that occurred on upward optokinetic stimulation were assumed to have appeared because upward and downward optokinetic nystagmus in the physiological state are not equal (contrary to horizontal-induced optokinetic eye movements). Downward nystagmus in healthy individuals is stronger than upward nystagmus [22]. This may be explained by the role of the positions of the maculae with reference to gravity. According to our observations, balance control was worse (greater longitudinal sway) when optokinetic stimulation was set upward, creating optokinetic nystagmus beating downward. The increase in previously-existing asymmetry of eye movement control in the vertical plane was followed by an increase in balance disturbances. Crevits et al [23], using a vertical pendulum, observed that forward body sway is accompanied by upward eye deviation. In humans, the range of upward eye movement is wider than it is downward. The slow phase of nystagmus induced by an upward optokinetic target is directed upward, so the longitudinal body sway may be expected to be greater, as shown in our study.

The effect of greater longitudinal sway could be observed both during horizontal optokinetical stimulation and after vertical incitement. No lateral instability was registered during vertical visual distur-

Table 4. Comparison of craniocorpographical parameters during Romberg's test when the intensity of visual stimulation is varied and when optokinetic and sinusoidal stimulation of the same velocity takes place (no significant differences).

Opk left 10°/s – opk left 20°/s	0.16	0.15	0.37	0.46
Opk right 10°/s – opk right 20°/s	0.34	0.41	0.20	0.50
Opk left 20°/s – sinus. horizontal 20°/s	0.15	0.22	0.36	0.20
Opk up 10°/s – opk up 20°/s	0.15	0.29	0.46	0.44
Opk down 10°/s – opk down 20/s	0.40	0.13	0.19	0.39
Opk up 20°/s – sinus.vertical 20°/s	0.05	0.44	0.08	0.22
Opk down 20°/s – sinus.vertical 20°/s	0.33	0.14	0.26	0.22

opk right – optokinetic stimulation to the right; opk left – optokinetic stimualation to the left; sinus. – sinusoidal stimulation

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bance. In general, lateral displacement was better controlled under various directions of visual disturbances than forward-backward body movement. Brandt et al [24] estimated that the cooperation of otoliths in the frontal plane is well-developed. When the otoliths from one side decrease impulse generation, their counterparts increase it in compensation, allowing the contraction of particular postural muscles to maintain balance. In the saggital plane, such contraction in reaction to the otoliths is slighter [24].

Consideration of the facts above leads to a list of several conditions that might be trained by means of craniocorpography with visual feedback. These are: unilateral labyrinth weakness with delayed compensation; lack of proprioceptive control; disturbance of visual input following, for example, constricted visual field or routine work with a machine in motion. Any condition in which cooperation of balance inputs is disrupted (even under physiological circumstances such as motion sickness), an improvement in postural control may be facilitated by use of individual, purpose-selected visual impulse generation. Craniocorpography appears to be good tool for monitoring the recovery.

Conclusions

1. Visual stimulation (optokinetic and sinusoidal) in a horizontal plane induced stronger postural disturbances than visual stimulation in the vertical plane.
2. Both horizontal and vertical optokinetic stimulation resulted in major longitudinal body sway; lateral body displacement was well-controlled during vertical visual disturbances.
3. Differences in the influence of horizontal and vertical visual disturbances were noted: body control was better during the optokinetic stimulation to the left and downward.
4. No significant effect of intensity of visual stimulus on balance was observed.

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