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Binaural Monopolar Galvanic Vestibular Stimulation Reduces Body Sway During Human Stance

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Summary

The influence of monopolar binaural galvanic stimulation of the vestibular system was studied on body sway. Subjects, with eyes closed, were standing on a hard support or on foam rubber. Their body sway was registered on a force platform at intervals of 50 s. Both polarities of direct current with intensity 1 mA were used as a galvanic stimulus during the whole recording interval. Changes of body sway amplitude and velocity were analyzed in situations with and without galvanic stimulation on two different support surfaces. In stance on the hard support, the cathodal polarization of labyrinths (in most subjects) reduced body sway velocity and decreased body sway slightly in the anteroposterior direction. Anodal polarization of labyrinths during 50 s did not affect the body sway parameters. The results on the foam rubber platform exhibited a significant reduction of body sway velocity induced by both anodal and cathodal polarization of the labyrinths. The decrease of body sway in the anteroposterior direction was also observed during cathodal polarization. The stabilizing effect of vestibular binaural monopolar stimulation on the upright stance was mainly observed in the postural control situation where the leg proprioceptive input was changed (stance on soft surface) and the role of vestibular input was more important.

Key words

Galvanic stimulation – Vestibular control of stance – Postural control

Introduction

Electrical stimulation of the vestibular apparatus evokes a specific motor reaction in human stance. Body-sway response is directed towards the anodal stimulus and away from the cathodal stimulus. Sensitive measurements of body sway on a force platform provide an opportunity to register these body tilts in the horizontal plane (Njiokiktjien and Folkerts 1971, Bizzo and Baron 1972). Electric current mainly influences the discharge frequency of the vestibular nerve (Löwenstein 1955, Goldberg *et al.* 1984). Binaural bipolar electric vestibular stimulation induced a deviation of the body in the lateral directions during human stance (Lund and Broberg 1983, Hlavačka and Njiokiktjien 1985). Anteroposterior body sway was evoked with a monopolar binaural galvanic stimulus of the vestibular nerves in normal subjects and recorded with a force platform (Magnusson *et al.* 1990). Cathodal monopolar binaural stimulation had no effect in the lateral direction, but produces a biphasic forward movement. Anodal stimulation moved the centre of gravity backwards, while there was no lateral displacement (Njiokiktjien and Folkerts 1971, Shulzhenko *et al.* 1983).

In most previous work, the postural responses in the anteroposterior direction were evoked by applying stepwise monopolar binaural current stimuli repeatedly. According to our information, there are few data about the influence of the continuous polarization of labyrinths on body sway in human upright stance. We can expect habituation or a time-dependent decrease of the effect of continuous direct current vestibular stimulation on body sway, similar to the reduction of postural responses to repeated sinusoidal galvanic stimuli (Hlavačka and Njiokiktjien 1986). Nevertheless, the question about the possible tonic postural responses evoked by a stabile monopolar binaural stimulus might be interesting to analyze. For this reason, human body sway was influenced by longlasting monopolar binaural galvanization of the vestibular apparatus. Special attention was paid to the stabilizing effect of this stimulation in postural control and to the specific influence of stimulus polarity.

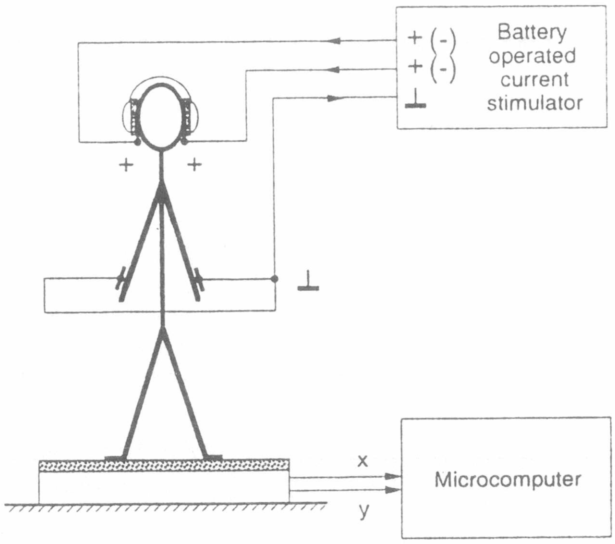

Fig. 1
The block diagram of the experiment.

Methods

Postural tests were performed on 19 healthy subjects, 13 males and 6 females, aged 18 to 43 years, mean age 25.5 years. The test session lasting 30 min included a sequence of six postural test measurements at 50 s interval, each followed by about a 5 min rest period to prevent fatigue. During the test, subjects were standing with eyes closed on the force platform, their hands hanging loosely along the body, and the heels close together with the feet forming an acute angle of 30 degrees. The subjects stood either directly on the hard support of the force platform or on foam rubber, 10 cm thick, placed on the force platform (Fig. 1).

The centre of body gravity of the subject in the upright stance was registered by means of a force platform constructed on 3 pressure transducers and equipped with automatic weight correction. Both continuous signals from the force platform were converted to digital form with sampling at a frequency of 20.48 Hz (1024 samples during a 50 s interval for one signal). The data were evaluated and monitored on a microcomputer (PMD). The stability of stance was characterized by four parameters. Their values were obtained by processing the lateral and anteroposterior signals from the force platform into the microcomputer. The following parameters were used:
– amplitude of lateral *Ax* and anteroposterior *Ay* stabilograms (4 SD – standard deviation of the stabilogram multiplied by four) characterizing the magnitude of body sway in both directions,
– velocity index of lateral *Ix* and anteroposterior *Iy* stabilograms (mean values of the first derivative of the stabilograms) reflecting the activity of postural muscles.

Continuous monopolar binaural galvanic stimulation of the labyrinths was carried out by two circular silver electrodes 25 mm in diameter, which were placed on both mastoids (Fig. 1). The reference stainless electrodes of rectangular form (3 x 2 cm) were affixed to the subject's wrists. Both stimulating and reference electrodes were covered with cotton wool and moistened with physiological saline. We used a battery operated two-channel current stimulator. The stimulating output current was gradually increased to intensity of 1 mA to avoid any postural reaction to the onset of stimulation. The stimulus was applied 5–10 s before the postural test and continued for 50 s. Both polarities of direct current (cathodal and anodal) of 1 mA intensity were used. The upright stance without galvanic vestibular stimulation was considered as the control situation. Industrial ear-muffs were used to prevent orientation from auditory cues and from the attachment of the stimulating electrodes. Prior to the investigation, informed consent was obtained from all the subjects in conformity with the Helsinki declaration.

Results

In most subjects, vestibular stimulation decreased body sway velocity and amplitude. The stabilizing effect of stimulation by equal direct current applied to both labyrinths was clearly expressed in the situation where the subjects were standing on foam rubber. During stimulation, the velocities and amplitudes of body sway were statistically reduced with both polarities of stimulating current when subjects were standing on foam rubber. When standing on a hard support surface the effect of electrical vestibular stimulation was weaker and was induced only by cathodal stimulation.

The results of galvanic stimulation (GS) on the hard surface are compared with the controls in Fig. 2. Cathodal polarization significantly decreased the velocity parameters in both directions, the amplitude parameters were affected in the anteroposterior direction only.

The results of GS during standing on foam rubber are shown in Fig. 3. The stabilization effect mainly concerns the velocity index values in the anteroposterior sway, that was weaker in response to cathodal stimulation and stronger to anodal stimulation.

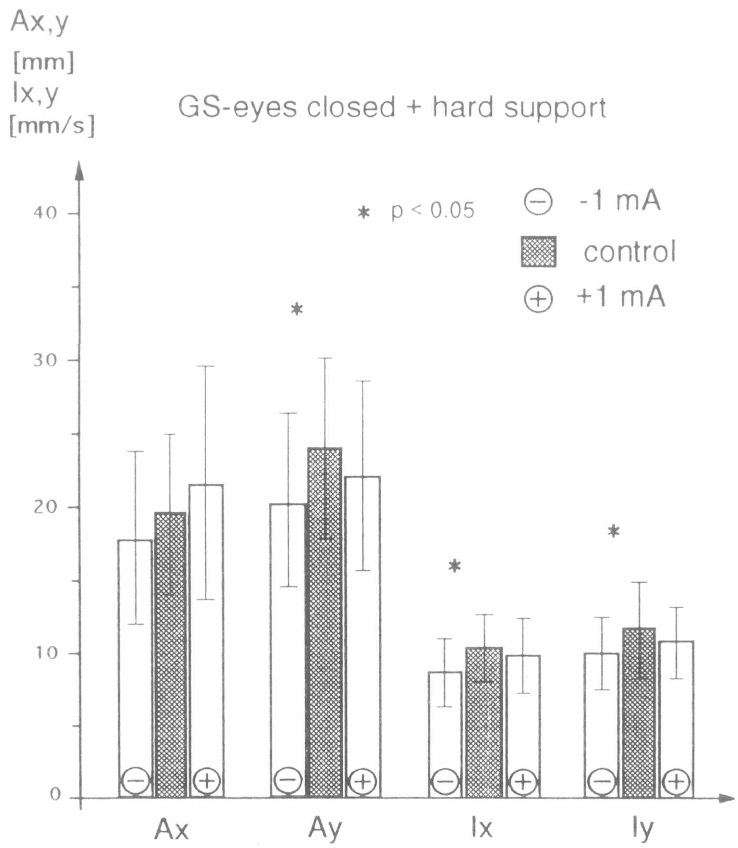

Fig. 2
The influence of galvanic vestibular stimulation on stance parameters while standing a hard support. Mean values (± S.D.), *Ax, Ay* – lateral and anteroposterior amplitudes, *Ix, Iy* – lateral and anteroposterior velocity indexes.

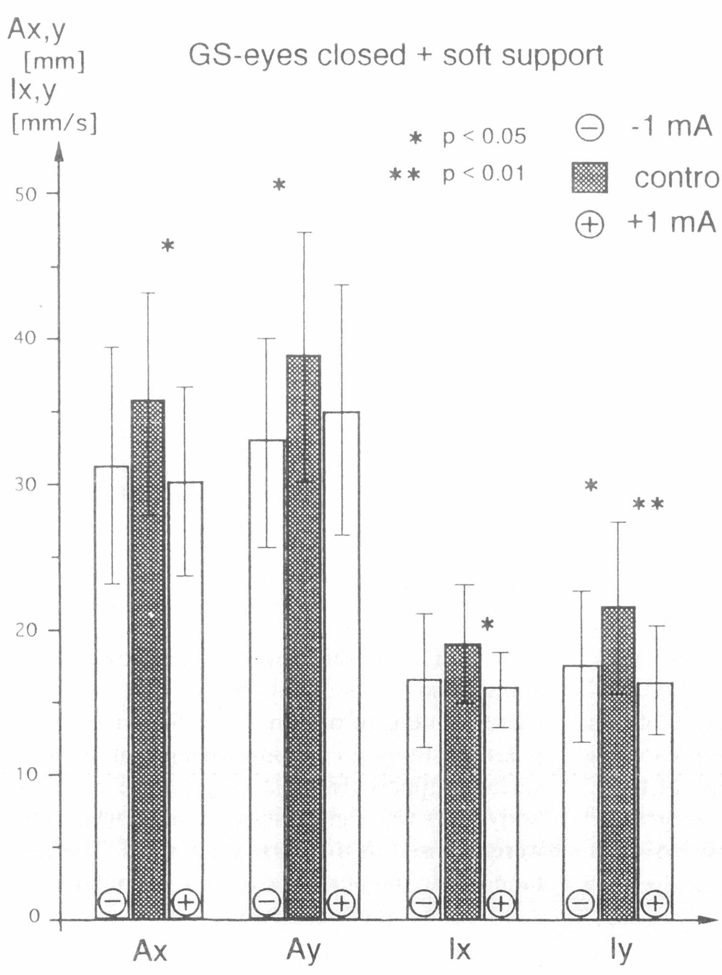

Fig. 3
The influence of galvanic vestibular stimulation on the stance parameters while standing on a soft support. Mean values (± S.D.), *Ax, Ay* – lateral and anteroposterior amplitudes, *Ix, Iy* – lateral and anteroposterior velocity indexes.

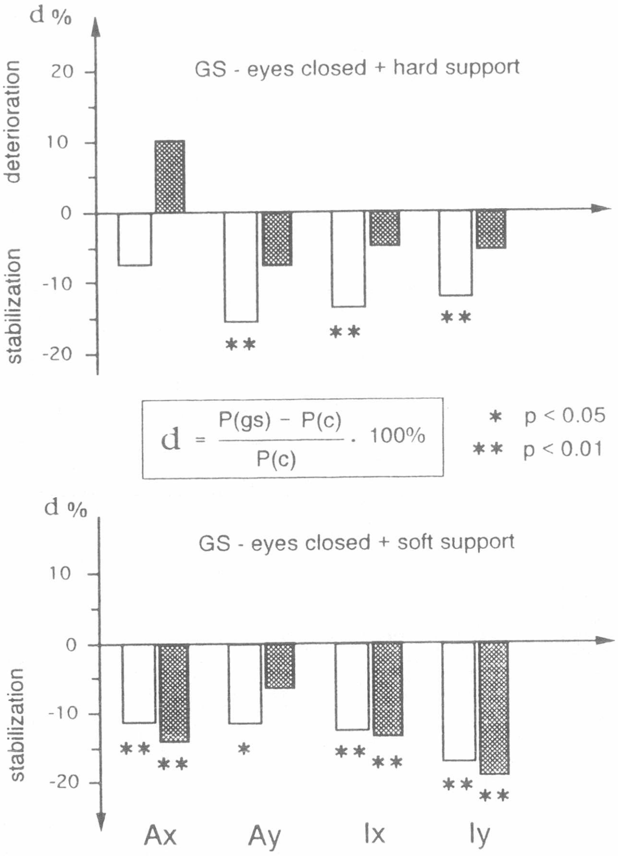

Fig. 4
The influence of anodal (black columns) and cathodal (white columns) vestibular stimulation on posture stability while standing on a hard support (above) and on a soft support (below) expressed in percentages: A – sway amplitude, I – sway velocity, x – lateral and y – anteroposterior sway direction. O – zero line -- mean parameter values in the control situation, d – relative difference, P(gs) – parameter values in a situation with stimulation, P(c) – parameter values in control situation.

A comparison of GS applied on the foam rubber versus control conditions is given in Fig. 4. To illustrate the observed influence of the stimulation employed, we expressed changes in the values of stabilometric parameters as relative values. The value of each parameter in the control situation was considered as the reference value and the value of this parameter during galvanic stimulation was expressed in percentages (Fig. 4). For statistical evaluation of these relative values we used the paired t-test. A greater stabilization effect was evident in response to both anodal and cathodal polarization.

The feeling of stiffness in leg postural muscles during the galvanic stimulation was present in the tested subjects. Although the EMG response was not measured here, this is in agreement with the results of decreased velocity of body sway (Fig. 4).

Sway velocity values of each of the 19 tested subjects is shown in Fig. 5, which illustrates that most subjects stabilized their stance. The improvement of standing stability expressed in percentage can be seen in the situation on foam rubber.

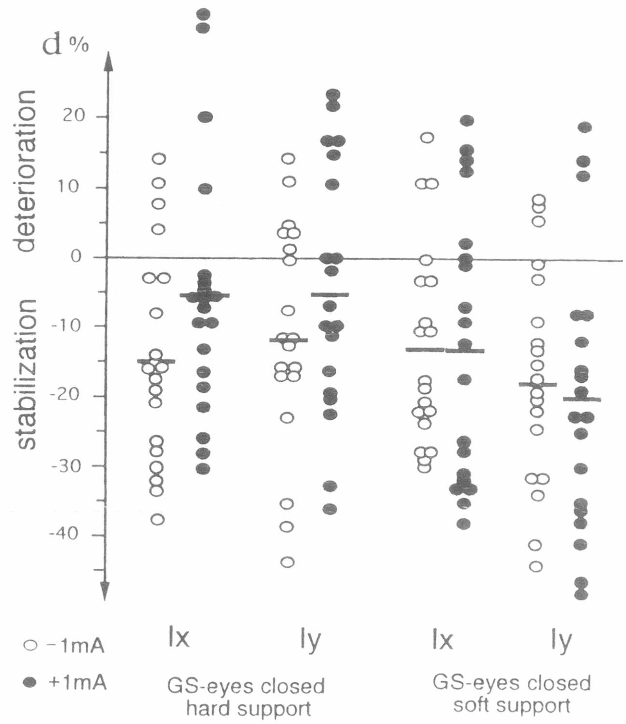

Fig. 5
The individual values of the changes of velocity indexes (*Ix*, *Iy*) in all tested subjects expressed in percentages. Left side – standing on hard support, right side – on soft support. Other description as in Fig. 4.

Discussion

The present results have shown that electrical stimulation of both labyrinths with the same direct current intensity of 1 mA for 50 s, irrespective of its polarity, stabilized the human upright stance on a soft surface support. In most subjects the mean velocity of body sway was significantly reduced when the subjects were exposed to the current stimulus. The influence of monopolar binaural vestibular stimulation on body sway during standing on a hard surface was weaker and only the cathodal stimulus had a significant stabilizing effect on stance (Fig. 4).

What could be the probable reason for the stabilizing effect of this type of stimulation? The essential difference between the previous approach (Njiokiktjien and Folkerts 1971, Magnusson *et al.* 1990) and our results is that we maintained the polarization of both labyrinths with the same polarity for 50 s continuously. The stimulus intensity was not altered during the recording. It has been reported that the galvanic postural responses are induced by changing the stimulus intensity. The cathodal stimulus excited and the anodal inhibited the discharge frequency in the vestibular nerve (Goldberg *et al.* 1984). In this way, the asymmetry between the activity of left and right labyrinths can be simulated. The equilibrium control centre which does not receive any change in cervical input responds to this asymmetry by lateral body tilt which is followed by a compensatory lateral body sway response. Similarly, a symmetrical increase or decrease of vestibular nerve activities can be induced resulting in anteroposterior body sway (Shuzhenko *et al.* 1983, Magnusson *et al.* 1990). Vestibular activity facilitates the antagonistic spinal reflex evoked from flexor or extensor muscles, indicating that the vestibular influence contributes to the muscular co-contraction necessary for the "pillar-like stability of weight bearing limb" (Gernandt *et al.* 1957). In this connection we can suppose that the tonus in leg postural muscles is increased during monopolar binaural stimulation. Some relation or similarities to lifting or falling reactions could also be assumed. During falling no phasic extension occurs but instead antagonist muscles contract together and this results in a certain stiffness of the limbs. This helps in the deceleration of the body and in landing (Lacour *et al.* 1978).

The involvement of vestibular information in stance control on a hard support is relatively less obvious, because the input from leg proprioceptors and support surface orientation inputs are available. In this situation, therefore, the inhibitory effect of small vestibular activity evoked by the anodal stimulation (+1 mA) was negligible (Fig. 4. upper part). On the contrary, excitation of the vestibulospinal loop by cathodal polarization of the labyrinths decreased body sway in the lateral direction and sway velocity in both directions.

A much more critical function of the vestibular input is apparent when subjects attempt to maintain their balance within altered sensory environments, for example standing with their eyes closed on a soft support surface. Experimental results suggest that in this situation the vestibular input automatically takes precedence (Nashner 1982). Both stimuli, anodal and cathodal polarization of the labyrinths, reduced sway velocity in both directions and sway amplitude in the lateral direction. The anteroposterior sway amplitude was positively influenced only by cathodal stimulation.

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