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Influence of a Light Tactile Contact on Vertical Posture Maintenance under the Conditions of Destabilization of Visual Environment

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Abstract—The influence of a light contact between index finger and a stationary external surface on the maintenance of upright posture in healthy subjects "immersed" in unstable virtual visual environment has been studied. Under these conditions, the subjects saw a screen with a visual scene consisting of a foreground and a background. In the foreground, there was a window of a room with the adjacent walls; in the background, there was an aqueduct with the adjacent terrain. The virtual visual environment was destabilized by setting inphase or antiphase couplings between the foreground and body oscillations. The analysis of upright posture maintenance was focused on the assessment of amplitude–frequency characteristics of two elementary variables calculated from the trajectories of the center of pressure of feet (CoP) in mediolateral and anteroposterior directions: the trajectory of vertical projection of the center of gravity (the CG variable) and the differences between the CoP and CG trajectories (the CoP-CG variable). Both in case of normal posture and the posture with a fingertip contact, the root mean square (RMS) values of the spectra of both variables were the lowest in motionless visual environment with antiphase coupling between the foreground and the body oscillations and the highest with inphase coupling and with eyes closed. In the cases with fingertip contact, the intensity of body oscillations in both directions was considerably lower; the influence of different visual conditions on RMS values of the spectra of both variables decreased. This effect was more significant for the CG variable. The frequency of body oscillations decreased as well. We observed the effect of tactile contact on the frequency of the spectra of both variables. The median frequencies of the spectra of the CoP-CG variable calculated from body oscillations in the anteroposterior and mediolateral directions increased under the conditions of tactile contact. On the contrary, the median frequencies of the spectra of the CG variable increased only for body oscillations in the mediolateral direction. Our results show that a light tactile contact (providing no mechanical support) significantly improves vertical posture maintenance, inter alia, under the conditions of destabilization of virtual visual environment. This improvement is provided by multidirectional and independent effects on the amplitude–frequency characteristics of elementary variables (CG and CoP-CG).

Keywords: vertical posture, tactile contact, visual destabilization, virtual visual environment

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The major challenge for the system of human postural control is to prevent the horizontal displacements of the body center of gravity (CG) going beyond the supporting contour. This challenge seems to be rather difficult for the neuronal mechanisms involved in such control. The difficulty consists in the fact that human body is a multi-link inverted pendulum. Nevertheless, the human CNS successfully solves this problem using intricate sensorimotor conversions, which continuously integrate various sensory inputs and coordinate numerous motor commands [1]. As a result, the stable position of the body during quiet standing is achieved, when the horizontal shifts of CG projections describe a much lesser area compared to the area of the supporting contour of feet.

However, quiet standing on a hard surface can be substantially improved by slightly (at a pressure of about 0.5–0.9 N) contacting an immobile object with a finger [2–5]. It should be noted that this value of contact force is in the center of the range of maximum sensitivity of mechanoreceptors in the skin of the fingertip [6]. It is supposed that substantial reduction of body oscillations at the smallest possible force of finger contact cannot be a result of mechanical support provided by the contact itself [7] but is associated with the involvement in postural control of the information about arm orientation and uses the feedback formed by signals from the tactile receptors of the fingertip [2, 3].

It is noteworthy that a light contact between an index finger and a stationary surface can substantially

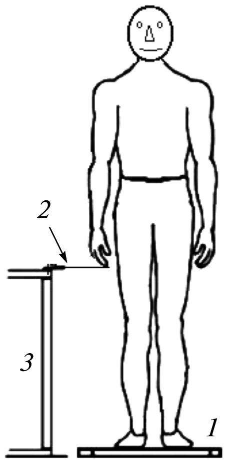

Fig. 1. Scheme of the experiment. A subject is standing on the stabilograph platform (*1*) with their arms down. In half of the tests, the arms are hanging freely; in other tests, the right forefinger touches upon a force-measuring plate (*2*) attached to a fixed stanchion (*3*).

stabilize posture in the patients with vestibular system disorders [8] and Parkinson's disease [9], as well as in blind people [10]. It also renders help in overcoming the effects of vibration of leg muscles [11] and biceps brachii [2], which destabilize vertical posture in healthy people. It should be noted that additional stimulation of tactile receptors, in particular, through weak vibration of a fingertip, results in the enhancement of their sensitivity and, as a consequence, intensification of the stabilizing effect of tactile contact on the posture [3, 12].

In spite of the numerous studies on the postural effects of a light tactile contact, its influence on the stability of the vertical posture under destabilization of visual environment has been little studied as yet. At the same time, cases of postural destabilization induced by visual signals are not infrequent in everyday life. In particular, the visual vertigo accompanied by spatial disorientation, anxiety and postural instability may occur in quite a number of neurological disorders (above all, vestibular disorders) and sometimes in healthy people [13–16]. It has also been shown that about one-third of people are susceptible to visual height intolerance, when not only sick, but also healthy subjects may feel dizzy and unbalanced [17–19].

The goal of this study was to determine the degree to which the spatial disorientation caused by destabilization of visual environment and its motor manifestations in a standing person can be suppressed by a slight tactile contact between a finger and an external object. Spatial disorientation was induced by the technique of manipulating visual environment by means of "immersing" subjects into a virtual visual environment (VVE) destabilized via its association with body oscillations [20, 21]. Such association allowed the establishment of either inphase or antiphase coupling (CC or AC, respectively) between body oscillations and visible 3D scene and thereby destabilization of vertical posture and substantial complication of the function of specific mechanisms of its visual control.

METHODS

The study was carried out in 13 apparently healthy subjects, including eight men (47.6 ± 5.3 years old) and six women (43.0 ± 5.2 years old), having no visual pathologies or old neurological diseases. All of them were preinformed about the experimental procedure and gave their written consent to participation in the experiments. During tests, the subjects maintained a comfortable vertical position while standing on a square platform of a stabilograph (40 × 40 cm, Stabiloplatforma-2, Design Office of the Research Engineering Institute, Balashikha, Russia), which was used to record the changes in the position of the center of pressure of feet (CoP) on the support (Fig. 1). The subjects' arms were down along the sides of the body and their feet were in a comfortable position: the heels were at a distance of 6–8 cm from each other and the feet were turned at an angle of 20–25 degrees.

Characteristics of tactile contact. In addition to normal standing, in half of the tests the subjects maintained their position by slightly touching the end of a flexible steel plate (contact condition) with the index finger of the right hand. The plate (20 cm in length) was attached at the other end to the horizontal surface of a fixed stanchion through a joint with a frontal axis of rotation (Fig. 1). Due to this structure, the plate not only was deflected when pressed, but also could shift sideways in the place of fingertip contact. Hence, it was impossible to use it as an additional mechanical support. The vertical force of finger pressure on the plate was assessed with a tensometric sensor built in the plate near the place of attachment. The training trials performed by all subjects before testing and the measurements during the main trials showed that the vertical force of pressure varied in the range of 0.4–0.8 N. The lateral shifts of the finger were no more than 2 mm.

Visual conditions. During vertical posture maintenance, the subjects looked at a screen (1.5 m in height and 2 m in width) made of the tissue not changing the degree of polarization of incident light (a *silver screen*). A 3D stereo image was formed on the screen by the so-called passive methods [22]. The two images of the same scene displaced relative to each other (the view of the aqueduct from the window) were simultaneously projected on the screen from two projection cameras (Sharp XR-10X) with polarization filters oriented orthogonally to each other. The subjects and the projectors were on the same side of the screen. During the tests, the subjects wore the glasses with polarization filters (3DS-GS (Panorama), Stel–Computer Systems, Moscow, Russia; the frequency of alternations, 120 Hz) oriented parallel to the respective filters of the projection cameras, which provided 3D perception of VVE. The visual field of the subjects was limited by the glasses, being approximately 60° vertically and 80° horizontally, and did not go beyond the limits of the screen. Under these conditions, they saw only a virtual 3D image with a foreground and a background. The foreground was a window of a room with adjacent walls and the background was an aqueduct with adjacent area. The distance of the former scene (foreground) from the subject was 1.2 m, while the distance of the latter scene (background) was about 20 m. Thus, the subjects could see only the presented VVE. During posture maintenance tests, they were asked to look at the background approximately at the center of the screen.

The maintenance of upright posture during the displacements of observable environment coupled inphase and antiphase to body oscillations was studied by making the positions of VVE foreground in the mediolateral and anteroposterior directions dependent on the shifts of CG as an indicator of body oscillations in similar planes. As a result of this positioning (connection), the shifts of VVE foreground occurred almost simultaneously (a delay of 25 ms) with body oscillations.

The shifts of CG and VVE foreground were related via the computer program in such a way that the experimenter could easily set the direction (antiphase or inphase) of displacement of the foreground of observable environment before each test. In this research, the coupling coefficient between displacements of the VVE foreground and the body was equal to 2; i.e., when the body moved, e.g., by 1 cm in the frontal plane, the VVE foreground was shifted in the same plane by 2 cm. Previously, we have shown that the subjects under such conditions, when correcting posture, involuntarily use the movable foreground, but not immovable background of VVE as a visual reference, which affects the characteristics of standing [20, 21]. As a result of manipulations with the direction of coupling between body oscillations and VVE, the subjects, according to their own reports, perceived the observable environment altogether as nonstationary, in spite of the immovable background.

Analysis of body oscillations. The trajectory of the center of pressure of feet (CoP) obtained by using a stabilograph was converted from analog into digital form (frequency of digitalization, 100 Hz) and then recorded on PC. In the subsequent analysis, it was decomposed as a sum of two functions of time along each (frontal and sagittal) axis. The quality of vertical posture maintenance was assessed by analyzing the changes in the amplitude–frequency characteristics of two elementary variables calculated from CoP movements on the support. One of them was the trajectory of projection of the center of gravity (the CG variable) and the other was the difference between the CoP and CG trajectories (the CoP–CG variable). They were calculated by the approach proposed in [23], which was thoroughly described and frequently used in quite a number of works [24–27]. Hence, only its basic principles will be given below.

The method for the calculation of the above elementary variables is based on the clear relationship between the changes in the CG and CoP oscillation amplitudes and oscillation frequency. In particular, it has been shown [27, 28] that the ratio of the amplitudes of these variables (CG/CoP) is the highest (approaching 1.0) at the minimum oscillation frequencies (close to 0.0 Hz) and the lowest (approaching 0.0) at the maximum frequencies (above 3 Hz). Hence, it could be concluded that the relatively high-frequency CoP oscillations have no effect on the value of CG oscillations. Indeed, it has been shown experimentally in the cited works that CoP oscillations with the frequencies above 0.5 Hz have actually no effect on the value of CG oscillations. In this context, we obtained elementary variables by using a low-frequency filter representing the ratio of oscillation amplitudes between CG and CoP and the relationship between CoP oscillation frequency and body movements [27, 28]. Before using this filter, the digitalized CoP trajectory was initially subjected to amplitude–frequency decomposition using the fast Fourier transform to obtain amplitude distribution as a function of frequency. After the CoP spectrum had been obtained, the above filter was used to obtain the CG spectrum, and the CG trajectory was restored over time using the inverse Fourier transform. Then the CG trajectory was subtracted from the CoP trajectory to obtain the signal of the CoP–CG variable and, accordingly, the CoP–CG spectrum. It should be noted that, as in the studies [26–28], the selected characteristic of the filter did not depend on anthropometric parameters of the subjects.

In further analysis of the results of displacement, CG was considered as a controlled variable and the CoP–CG difference was considered to be a variable related to body acceleration and reflecting the changes in resultant rigidity in ankle joints and the muscular efforts correcting oscillations of the center of gravity of the body [27–29]. The influence of experimental conditions on vertical posture maintenance was assessed by analyzing the changes in the median frequency (*MF*) and the root mean square (*RMS*) value of amplitude spectra in the ranges of 0–0.5 Hz and 0–3.0 Hz for the CG and CoP–CG variables, respectively.

The computer program of frequency filtration of CoP oscillations for distinguishing the CG and CoP–CG variables and the subsequent calculation of *MF* and *RMS* oscillation spectra was written in the Matlab environment.

Procedure. While testing posture maintenance, the subjects were instructed to look at any object of immovable background and to minimize body oscillations. The inphase or antiphase couplings (IC and AC) between visual environment and body oscillations were established at random in individual tests. The

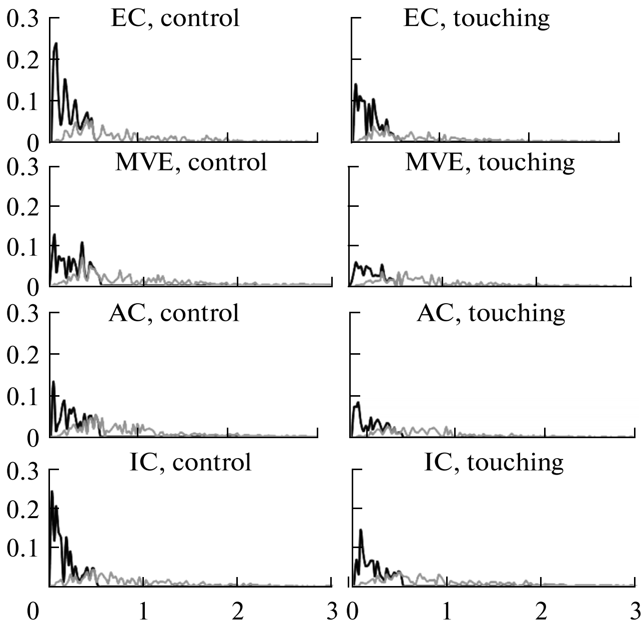

Fig. 2. Examples of the amplitude spectra for CG (black) and CoP–CG (gray) variables obtained by the analysis of body oscillations when standing in a normal position (control) and when standing with an additional tactile contact (touching) under different visual conditions: motionless visual environment (MVE), with the eyes closed (EC), antiphase coupling (AC), and inphase coupling (IC) of oscillations of the foreground of virtual visual environment with body oscillations.

tests with the association between the VVE foreground and body oscillations alternated with the tests with standing in a motionless visual environment (MVE) and the tests with complete elimination of visual control (eyes closed, EC). Under the conditions of MVE, the subjects stood wearing the same stereo glasses and their field of vision was limited similar to the conditions of association between oscillations of the body and the foreground. They saw a screen in front of them, with the image of the same virtual 3D scene, but neither foreground nor background was associated with body oscillations.

During the experiment, the subjects performed 32 tests: 16 ones under normal standing conditions (the control) and 16 ones when standing with a fingertip contacting the surface of a flexible plate. In both cases, every 16 tests included 4 testes under the conditions of IC, 4 testes under the conditions of AC, and the tests under the conditions of MVE and EC (4 tests for each condition). The duration of stabilogram recording in a test was 40 s. The time interval between the tests was about 1 min; after every four or five tests, the subjects had a rest for 3–4 min when seated, without changing the position of their feet. Visual conditions, as well as the presence of a tactile contact between the finger and the plate were alternated randomly during the experiment.

The results of all tests were averaged for each visual condition, first for individual subjects; then the mean values were calculated for the entire group. During statistical analysis, the global influence of the factors of "visual conditions" and "tactile contact" on variables under study was assessed by the single-factor analysis of variance (ANOVA). The reliability of differences between *RMS* and *MF* during pairwise comparison of individual visual conditions was assessed by the post-hoc analysis using the unequal-variance *t* test.

RESULTS

Figure 2 shows the amplitude spectra calculated from the CG and CoP–CG trajectories in the anteroposterior direction by the results of testing a typical subject. As one can see, the tactile contact of index finger considerably reduced the oscillation values of both variables, demonstrating postural stabilization under all visual conditions. In addition, different visual conditions had different effects on the spectra of variables under study. It is easy to see the lower amplitudes of oscillation spectra of the CG variable, both for normal standing and for standing with a contact under the conditions of MVE and AC (antiphase coupling) compared to EC and IC (inphase coulping). In other words, the subject stood more stably under the first two visual conditions. These and other effects of fingertip contact on the amplitude–frequency characteristics of oscillations of the studied variables summarized for all subjects are presented in more detail in Figs. 3 and 4.

Analysis of RMS oscillation spectra of the studied variables. Figure 3 shows the averaged *RMS* of amplitude spectra for the CG and CoP–CG variables calculated from the results of analysis of stabilography signals recording the support reactions in the sagittal and frontal planes.

It can be seen from Fig. 3 that the values of spectral oscillations of both variables under the conditions of tactile contact were much less than the normal value. This was confirmed by the analysis of variance demonstrating the global effect of the "tactile contact" factor on *RMS* of the spectra of both variables. For the CG and CoP–CG variables of anteroposterior direction, the F-ratio test $F_{1,381} = 42.93$, $P < 0.000000001$ and $F_{1,381} = 15.85$, $P < 0.00001$, respectively. For the CG and CoP–CG variables of mediolateral direction, $F_{1,381} = 91.09$, $P < 0.00000000001$ and $F_{1,381} = 47.69$, $P < 0.00000000001$, respectively.

The post-hoc comparisons of *RMS* of the spectra of variables under study using two-sample *t* test showed that the tactile contact of the fingertip was effective under all visual conditions for body oscillations in both anteroposterior and mediolateral direction (see Table 1).

Figure 3 and Table 1 show that severity of the impact of the "visual conditions" factor on *RMS* of the spectra of the CG and CoP–CG variables depended on the presence or absence of tactile contact.

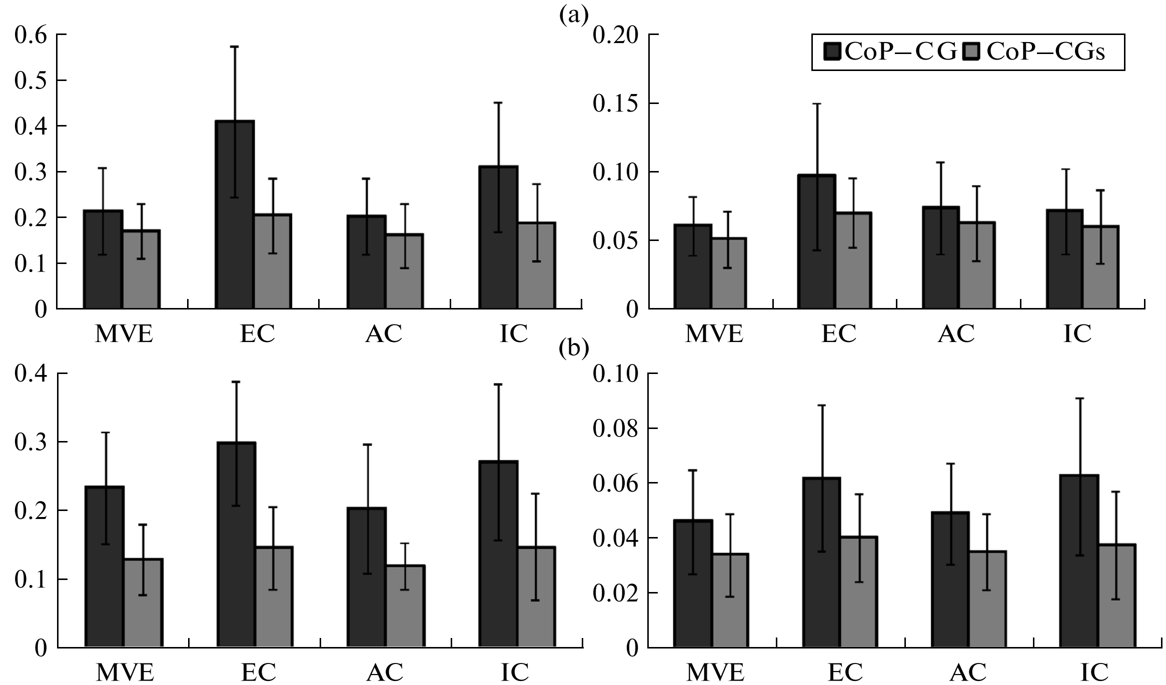

Fig. 3. *RMS* (mm) of the spectra of CG and CoP–CG variables and their standard errors calculated from body oscillations in the anteroposterior direction (a) and in the mediolateral direction (b) in the motionless visual environment (MVE), with the eyes closed (EC), antiphase coupling (AC) and inphase coupling (IC) of oscillations of the foreground of virtual visual environment with body oscillations. The results of processing the tests with the tactile contact are marked with the letter "c".

Anteroposterior direction of oscillations. The analysis of variance showed a statistically significant effect of the "visual conditions" factor on *RMS* of the spectra of the CG variable under normal standing: the F-ratio test $F_{1,191} = 15.09$, $P < 7.3013E\text{-}09$, and the absence of significant effect under the conditions of tactile contact: $F_{1,191} = 2.32$, $P > 0.05$. The weakening of visual effects under the conditions of tactile contact was revealed also for the CoP–CG variable: during tactile contact, $F_{1,191} = 3.58$, $P < 0.005$, while during posture maintenance in the absence of tactile contact, $F_{1,191} = 6.41$, $P < 0.0005$.

Mediolateral direction of oscillations. The analysis of variance for this direction of body oscillations revealed further weakening of visual effects under the conditions of tactile contact. While the statistically significant effect of the factor of "visual conditions" on *RMS* of the spectra of the CG variable under normal standing conditions was obvious: the F-ratio test $F_{1,191} = 4.57$, $P < 0.005$, the absence of significant effect of visual conditions during tactile contact was also obvious: $F_{1,191} = 1.06$, $P > 0.3$. The influence of the factor of "visual conditions" on the CoP–CG variable was similar. Under normal standing conditions, the F-ratio test $F_{1,191} = 4.01$, $P < 0.01$, while no significant effect of this factor was observed during tactile contact: the F-ratio test $F_{1,191} = 1.41$, $P > 0.2$.

Analysis of MF of the oscillation spectra of variables under study. Figure 4 shows the averaged *MF* of amplitude spectra for the CG and CoP–CG variables.

Figure 4 shows an increase in median frequency of the spectra of the studied variables under most conditions as a result of tactile contact. The analysis of variance showed the global effect of the "tactile contact" factor on *MF* of the CG and CoP–CG variables of mediolateral direction (the F-ratio test: $F_{1,381} = 28.89$, $P < 0.00000001$ and $F_{1,381} = 58.5$, $P < 1.82E\text{-}13$, respectively) and on *MF* of the CoP–CG variable of anteroposterior direction ($F_{1,381} = 45.09$, $P < 7.09E\text{-}11$). However, the analysis of variance revealed no global effect of the "tactile contact" factor on *MF* of the CG variable of anteroposterior direction.

The post-hoc comparisons of *MF* of the spectra for individual visual conditions showed that the tactile contact had less influence on the frequencies than it was shown for *RMS* of the spectra. In particular, in the analysis of body oscillations in the anteroposterior direction, this method revealed no statistically significant changes in *MF* of the CG variable on transition to standing with the tactile contact for all visual conditions (see Table 2).

The global effect of the "visual conditions" factor on *MF* of the spectra of the CG and CoP–CG variables was much weaker than on *RMS* of the spectra of these variables. The analysis of variance of the oscillations in the anteroposterior direction showed a statis-

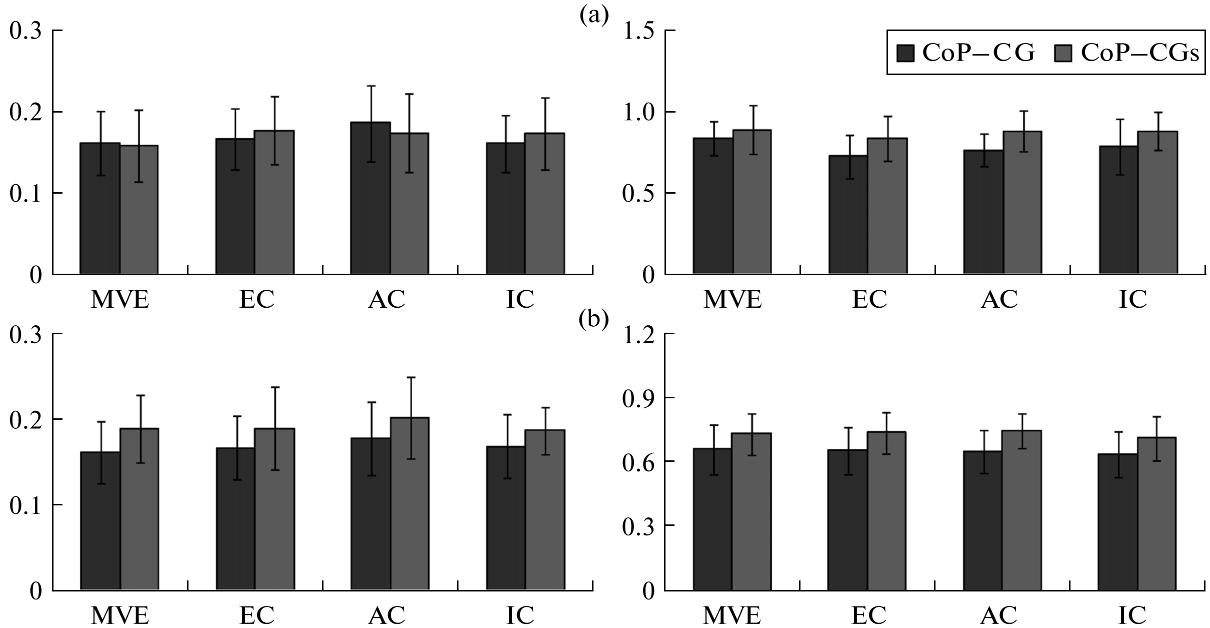

Fig. 4. The median frequencies (*MF*, Hz) of the spectra of CG and CoP–CG variables and their standard errors calculated from body oscillations (a) in the anteroposterior direction and (b) in the mediolateral direction under different visual conditions. Other designations are the same as in Fig. 3.

tically significant effect of this factor on *MF* of the spectra of the CG variable under normal standing conditions: the F-ratio test $F_{1,191} = 4.17$, $P < 0.007$, and the absence of its significant effect under the conditions of tactile contact: $F_{1,191} = 1.76$, $P > 0.155$. The leveling of visual effects under the conditions of tactile contact was also shown for the CoP–CG variable ($F_{1,191} = 1.70$, $P > 0.16$), while the statistically significant effect of this factor was observed in the absence of tactile contact ($F_{1,191} = 5.41$, $P < 0.002$).

For the mediolateral direction of body oscillations, the analysis of variance showed no statistically significant effects of the "visual conditions" factor on *MF* of the spectra of both variables. For the CG variable under normal standing conditions, the F-ratio test gave the value $F_{1,191} = 1.46$, $P > 0.22$; for the conditions of tactile contact, $F_{1,191} = 0.92$, $P > 0.43$. The influence of the "visual conditions" factor on the CoP–CG variable was nearly the same. Under normal standing conditions, the F-ratio test $F_{1,191} = 0.41$, $P > 0.74$; during tactile contact, $F_{1,191} = 0.98$, $P > 0.39$.

DISCUSSION

Numerous studies have shown that a light tactile contact with external environment (without providing physical support) may have a substantial effect on human movements and, in particular, vertical posture maintenance, as well as on the perception of spatial position of the body [2–8]. These observations suggest that tactile contact provides the movement control system with additional information about spatial orientation and oscillations of the body, which is used for postural stabilization.

On the other hand, vision also informs CNS about body oscillations relative to the external environment and about the stationary state of the external environment. In this context, it would be important to assess the efficiency of contribution of the sensory signals induced by tactile contact to the regulation of vertical posture under the conditions when the stationary state of observable environment is disturbed [13–16, 30] and it becomes difficult to use this environment as a reference system. We believe that our study provides factual data largely answering this question.

The results showed that the amplitude of body oscillations in both anteroposterior and mediolateral direction considerably decreased under all visual conditions in the case of a fingertip contact with an external object. The quantitative assessment of changes in the spectra of the CG and CoP–CG variables revealed a more substantial decrease in *RMS* of the spectra of the CG variable compared to the CoP–CG variable. Since the CoP–CG variable reflects the changes in the resultant ankle joint stiffness [24, 27–29], this means that postural stabilization under the conditions of fingertip contact with the external environment was largely mediated by the neuronal mechanisms and feedbacks influencing directly the amplitude of body oscillations and, to a lesser extent, due to variation of the physical state of muscles resulting in enhanced joint stiffness. This conclusion is also supported by assessment of the influence of tactile contact on the median frequency (*MF*) of the spectra of the CoP–

Table 1. The reliability of differences between *RMS* of the spectra of CG and CoP–CG variables obtained by comparing them under normal conditions and under the conditions of tactile contact

	CG	CGc	*t*-statist.	$P(T \leq t)$	CoP–CG	CoP–CGc	*t*-statist.	$P(T \leq t)$
Body oscillations in the anteroposterior direction								
MVE	0.22 (0.09)	0.17 (0.06)	2.193	0.015	0.061 (0.02)	0.052 (0.02)	2.185	0.0157
EC	0.41 (0.16)	0.21 (0.08)	4.711	8.57E-06	0.096 (0.04)	0.069 (0.025)	2.691	0.0046
AC	0.20 (0.08)	0.16 (0.07)	2.652	0.0047	0.074 (0.03)	0.063 (0.026)	1.753	0.0415
IC	0.31 (0.01)	0.19 (0.08)	4.915	2.4Å-06	0.071 (0.03)	0.059 (0.026)	1.918	0.0291
Body oscillations in the mediolateral direction								
MVE	0.24 (0.08)	0.13 (0.05)	4.812	0.000003	0.047 (0.02)	0.035 (0.015)	3.281	0.00074
EC	0.30 (0.09)	0.15 (0.06)	5.865	7.03Å-08	0.063 (0.03)	0.041 (0.016)	4.801	3.73Å-06
AC	0.21 (0.095)	0.12 (0.035)	4.153	3.85Å-05	0.050 (0.02)	0.036 (0.014)	4.118	0.00004
IC	0.28 (0.11)	0.15 (0.08)	4.736	4.21Å-06	0.064 (0.03)	0.039 (0.02)	3.309	0.00078

Here and in Table 2: CG, center of gravity; CoP, center of pressure of feet; MVE, motionless visual environment; EC, closed eyes; IC and AC, inphase and antiphase coupling, respectively. The variables during tactile contact are marked with the letter "c." The presented data show the average values of *RMS* (± standard deviation, mm) for the whole group of subjects.

Table 2. The reliability of differences between *MF* of the spectra of CG and CoP–CG variables obtained by comparing them under normal conditions and under the conditions of tactile contact

	CG	CGc	*t*-statist.	$P(T \leq t)$	CoP–CG	CoP–CGc	*t*-statist.	$P(T \leq t)$
Body oscillations in the anteroposterior direction								
MVE	0.16 (0.03)	0.158 (0.04)	0.481	0.316*	0.824 (0.10)	0.886 (0.14)	–2.046	0.0220
EC	0.166 (0.03)	0.177 (0.04)	–1.329	0.093*	0.716 (0.13)	0.831 (0.13)	–3.956	0.0001
AC	0.186 (0.05)	0.173 (0.05)	1.299	0.098*	0.767 (0.099)	0.878 (0.12)	–4.654	0.00001
IC	0.161 (0.03)	0.164 (0.04)	–0.381	0.352*	0.776 (0.15)	0.88 (0.11)	–3.5	0.00039
Body oscillations in the mediolateral direction								
MVE	0.16 (0.035)	0.187 (0.04)	–3.578	0.000270	0.662 (0.12)	0.734 (0.09)	–3.31	0.00067
EC	0.165 (0.035)	0.19 (0.05)	–2.61	0.00531	0.655 (0.11)	0.739 (0.10)	–4.051	0.00005
AC	0.175 (0.04)	0.20 (0.045)	–2.49	0.0073	0.65 (0.10)	0.746 (0.08)	–5.154	0.000001
IC	0.17 (0.037)	0.19 (0.027)	–2.76	0.00356	0.638 (0.11)	0.713 (0.10)	–3.536	0.0032

The variables during tactile contact are marked with the letter "c". The presented data show the average values of *MF* (± standard deviation, Hz) for the whole group of subjects.

CG variable. In particular, Figs. 3 and 4 show that *MF* of the spectra of this variable though increased, which was the evidence of slight enhancement of muscle and joint stiffness, but not to the extent when the amplitude component of the spectra was reduced.

It would also be interesting to mention that the increase in *MF* of the spectra of the CG variable was revealed only for body oscillations in the mediolateral plane but not for its oscillations in the anteroposterior plane. The causes of such difference are still unclear and need further experimental testing. Probably, this is a manifestation of the characteristics of visual perception of the oscillations of external environment in different planes. Nevertheless, this fact additionally confirms the stabilization of vertical posture during tactile contact via differently directed and mutually independent effects on the amplitude and frequency characteristics of the elementary variables (CG and CoP–CG) of the process of vertical posture maintenance.

The results showed that the influence of visual conditions destabilizing the posture (the eyes closed, inphase coupling) became insignificant under the conditions of tactile contact. This confirms the previously made assumption [2–4, 7] that a light tactile contact, by stabilizing posture, provides the system of vertical posture control with additional information about body position in space.

We believe that the results of this and other investigations on the influence of a light tactile contact on human posture and movements could be useful for the development or specification of rehabilitation techniques for the patients with different sensorimotor disorders and impairment of spatial perception. The possibility of using the effects of tactile contact to improve the tools of rehabilitation techniques for such patients is demonstrated in quite a number of works [10, 12, 25, 30–32], although it would be enough to refer to only one research to support this conclusion. That study has shown, in particular, that, in the patients blind by birth, the use of a walking stick, which creates a light contact with a support, results in the same postural stabilization as with the usual load-bearing contact of a walking stick that really provides additional mechanical support [31].

CONCLUSIONS

(1) A light tactile contact, providing no additional mechanical support, substantially improves posture maintenance under the conditions of destabilization of observable environment. At the same time, the effect of tactile "reference" neutralizes the effects of visual conditions on equilibrium control.

(2) The posture maintenance under the conditions of destabilization of observable environment was improved by differently directed and mutually independent effects on the amplitude and frequency characteristics of elementary variables (CG and CoP–CG).

(3) The results of this investigation of the effects of a light tactile contact on human posture and movements can be useful for the development or specification of rehabilitation techniques for the patients with different sensorimotor disorders and impairments of spatial perception.

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