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SHORT COMMUNICATIONS

Relationship between Postural Oscillations on an Unstable Support and Variations of the Force of Grip on a Hand-Held Object

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Abstract—The relationship between postural oscillations and variations of the force of grip on a finger-held object while keeping balance on an unstable support was studied. The distribution median of the intervals between peaks in the sagittal stabilogram and the nearest peaks in the grip force recording from one and the same test proved smaller than that obtained from different tests. The proportion of intervals shorter than 175 ms was greater in real records than in "fictitious" ones. Thus, there is a connection between changes in the grip force and postural oscillations, and the balance control system can use signals from finger skin receptors to improve the stability of an upright posture.

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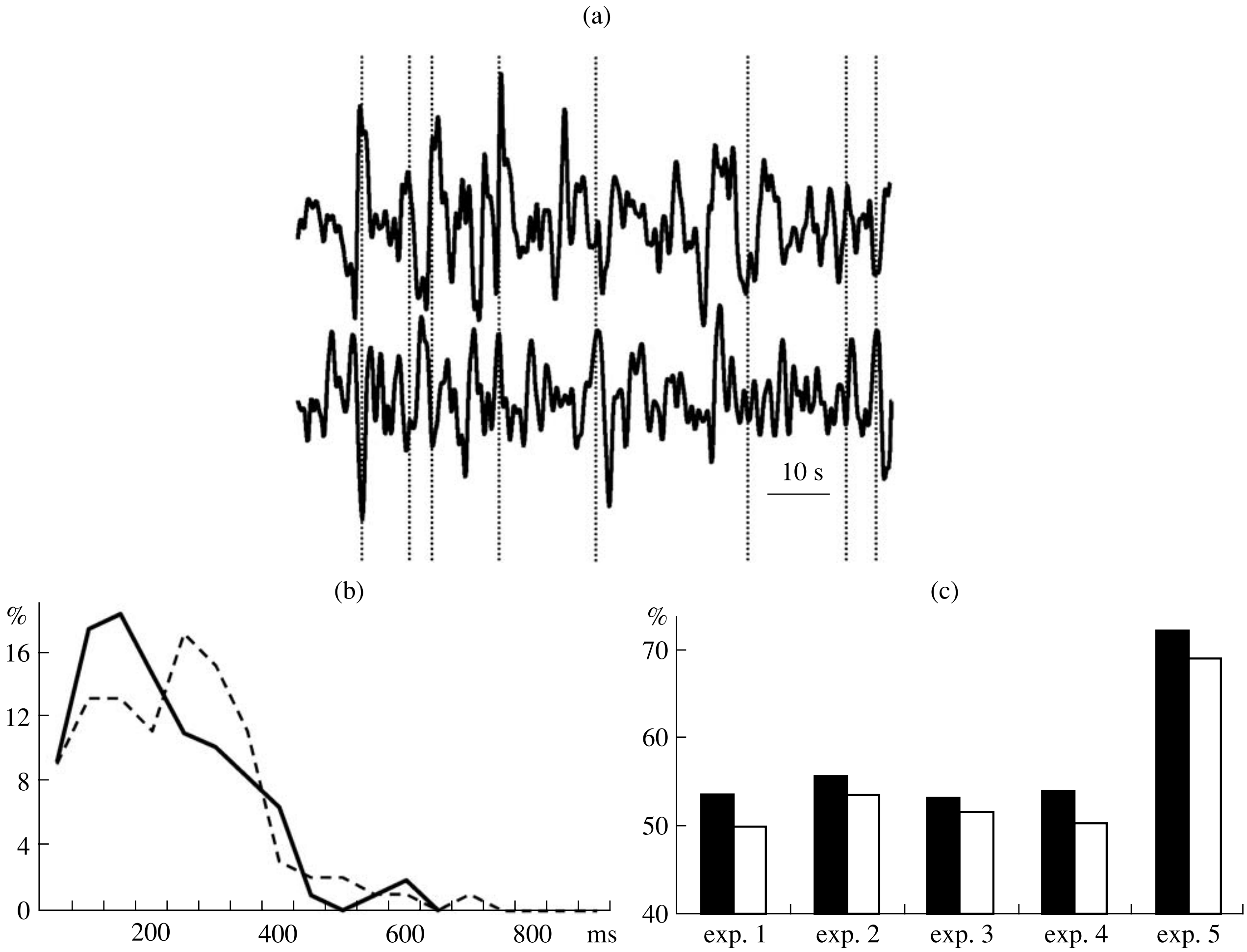
To solve the problem of maintaining an upright posture, the postural control system uses afferent signals differing in modality. The main source of postural information is the proprioception of the ankle muscles. These signals have a strong effect on the upright posture control system even in the case of their obvious discordance with the actual situation. To illustrate, under vibratory stimulation, the postural control system deflects the body from the vertical position in response to elevated afferent input, which sometimes even results in loss of balance. The postural information is provided by vision and vestibular and tactile sensitivity. This afferent information is frequently used subconsciously. For instance, a point contact of the subject's hand with a hard external object reduces postural oscillations, so that the responses to the vibration of the ankle muscles become less manifest [1]. This reduction is apparently due to the fact that the ankle angle signals on an unstable support no longer adequately reflect the body position, and the postural control system uses the afferent signals associated with the contact. If the external object moves slowly, the bodily movement also follows this displacement, but the subject does not relate the movement of the external object to that of the body [2]. Postural control can rely on very small modulations of afferent signals. It has recently been demonstrated that holding a small weight between the thumb and index finger reduces postural oscillations on an unstable support [3].

The afferent signals from the finger-cushions are modulated by the inertial motion of the finger-held weight, and one can suppose that this information is being used by the upright posture control system. The objective of this work is to verify this assumption. We supposed that if the afferent information from the finger pads was actually used, the grip force modulation and the bodily movements could be related with each other.

We examined five apparently healthy subjects aged between 23 and 58 years that gave their informed consent to participation in the experiment.

A subject stood on a see-saw support 10 cm high, with a bearing surface 32 cm in radius. The bearing surface was placed on a stabilograph to record the movements of the center of pressure (the sagittal stabilogram). Since the subject rotated the platform of the support in response to his postural oscillations, the variations in the position of the center of pressure corresponded to the ankle joint movements. The subject held between his thumb and index finger a compressive force transducer from which various weights could be suspended. The variations of the force of grip on the transducer in response to postural oscillations were recorded (the grip force recording). The subject held the upper arm along the body, the forearm being bent at an angle of 90 degrees at the elbow. Tests were conducted without any weight and with 200- and 500-g weights suspended from the transducer. The test duration was 60 s. The tests were repeated three times for each weight in a random sequence. The data obtained were read with a frequency of 2000 s^{-1} into a computer. For analysis, the data obtained under similar conditions were processed simultaneously. A filter with a cutoff frequency of 0.1 Hz was used to isolate slow signal variations from the recordings, the rest of the signals being smoothed out with a 1-Hz low-pass filter. The points of minima no less than 250 ms away from the other minima were then found in the smoothed signal recordings. The same procedure was used to find the points of maxima. Thereafter, the occurrence times of



Relationship between variations in a sagittal stabilogram and grip force recording. (a) An example of a simultaneous recording of the sagittal stabilogram (top) and grip force variations (bottom). The dotted lines are drawn through some coinciding peaks in both recordings. The time mark, 10 s. (b) Distributions of the absolute values of the intervals between peaks in the stabilogram and the nearest peaks in the grip force recording for the normal (the solid line) and a "fictitious" (the dashed line) recordings for a single experiment. The *y* axis shows the proportion of intervals in the respective 50-ms range; the *x* axis shows time. (c) The proportion of intervals shorter than 175 ms for the normal (solid bars) and "fictitious" (open bars) recordings. The *y* axis shows the percentage of the intervals; the *x* axis, individual experiments (exp.).

the minima and maxima were combined into a single sequence of the moments of occurrence of peaks for each signal. The mean values and standard deviation of intervals between peaks in sagittal stabilograms and grip force recordings were then computed. To establish the relation between signals, we computed the mutual intervals between peaks in sagittal stabilograms and the nearest peaks in the associated grip force recordings. To characterize the distribution of these intervals, we calculated their mean values and standard deviations. Because the distributions of the peak-to-peak intervals differed materially, we additionally computed the median and the ratio between the number of intervals shorter than 175 ms and the total number of intervals. The statistical test consisted in comparing the "fictitious" mutual intervals obtained in simultaneously processing sagittal stabilograms and grip force recordings taken from different tests with actual mutual intervals by means of Student's *t* test. The level of statistically significant differences was taken to be 0.05.

Figure a presents a fragment of recordings made in an experiment with a 500-g weight suspended from a finger-held transducer. One can easily see coincident extrema in the sagittal stabilogram and the grip force recording. The dashed lines in the figure are drawn through some such extrema. Comparison between intervals recorded in experiments with different finger-held weights showed no weight dependence. For individual subjects, the mean interval between extrema in the sagittal stabilogram was in the range 810–880 ms (group average, 828 ± 40 ms), their standard deviation ranging between 460 and 670 ms (group average, 527 ± 94 ms). The mean interval between peaks in the grip force recording was 850–980 ms (group average, 924 ± 55 ms), and their standard deviation, 390–480 ms (group average, 445 ± 43 ms). The interval between an extremum in the sagittal stabilogram and the nearest extremum in the grip force recording was around zero (from –10 to 20 ms; group average, – 1 ± 12 ms), with a standard deviation of 240–250 ms (group average, 249 ± 9 ms). Thus, the variance of the mutual intervals is approximately half as great as that of the intervals in the sagittal stabilogram.

Figure b shows the distributions of the actual and "fictitious" mutual intervals in the experiment, irrespective of whether a peak in the grip force recording occurred before or after the respective peak in the sagittal stabilogram. It can be seen that the distribution of the actual intervals is shifted towards smaller values. The average of the distribution medians of the mutual intervals for all the subjects was 150 ms (ranging from 151 to 164 ms). For the "fictitious" intervals, the average median was 168 ms (ranging from 164 to 176 ms), this difference being statistically significant (the paired *t*-test, $p < 0.05$). For each subject, the proportion of actual intervals shorter than 175 ms was greater than that of their "fictitious" counterparts (figure c, paired *t*-test, $p < 0.05$).

Thus, the distribution of the actual mutual intervals is shifted towards smaller values, as compared with that of the "fictitious" intervals, the proportion of short intervals being greater for the actual mutual intervals than for the "fictitious" ones. One can suppose that the greater proportion of short actual mutual intervals is due to the existence of a correlation between sagittal stabilograms and their associated grip force recordings. Since modulation of the grip force is accompanied by variations in the afferent input from skin receptors [4], one can assume that this afferent input can be used for stabilization of the upright posture when a subject stands on an unstable support. Note that the distribution of the peak-to-peak intervals is characterized by a high variance, and the difference between the actual and "fictitious" intervals is of statistical character. However, such a weak relationship between variations in sagittal stabilograms and their associated grip force recordings is natural, considering that the effect of a weight being held by fingers on postural oscillations also manifests itself in a small, though statistically significant, reduction of the postural oscillation amplitude in a situation where use should be made of any afferent signals in order to keep balance [3].

It is well known that, in a walking subject, the force of grip on a hand-held object is modulated in accordance with the inertial load developing during the walk [5]. A change in the grip force in this case precedes the occurrence of a load, which makes it possible to assume that the hold on the object and the bodily movement are controlled on the basis of a unified model of internal represenation of motion [5]. It can be assumed that the balance control system can use afferent information from skin receptors, along with its unified inherent model effecting the integration of signals differing in modality.

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