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Effect of Whole Body Vibration on the Rat Brain Content of Serotonin and Plasma Corticosterone

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Summary. To investigate the effects of whole body vibration on the central nervous system, rats were exposed to various whole body vibrations and changes in whole brain levels of Serotonin (5-HT) and 5-hydroxyindoleacetic acid (5-HIAA) were then determined. Changes in plasma corticosterone levels were also determined and related to the changes in the whole brain levels of 5-HT and 5-HIAA. The dose-related changes in the 5-HT and 5-HIAA levels were observed as acceleration increased from 0.4G to 5.0G. Changes in vibration frequency also affected the 5-HT and 5-HIAA levels of brain: they were significantly elevated at a frequency of 20 Hz ($P < 0.05$). Plasma corticosterone levels increased as acceleration increased from 0.4G to 5.0G. As the vibration frequency was changed from 5 Hz to 30 Hz, plasma corticosterone levels also rose significantly ($P < 0.05$) but the extent of elevation was approximately the same at each frequency. The correlation between brain 5-HT and plasma corticosterone levels with increasing acceleration ($r = 0.93$, $P < 0.01$) was significant.

Key words: Whole body vibration – Brain serotonin – Plasma corticosterone

Introduction

The responses of mammals to environmental stimulation inevitably involve central nervous activities. There are, however, few studies on the effect of whole body vibration on the central nervous system. Therefore, in this study we have tried to determine the effects of vibration stress on the whole brain contents of neuro-transmitters. We have measured the effects of whole-body vibration on the indoleamine, Serotonin (5-HT), which is one of the biogenic amines known to be neuro-transmitters in the brain, and on its main metabolite, 5-hydroxyindoleacetic acid (5-HIAA). We also investigated the response of plasma corticosterone to this stress and examined the relation between the changes in brain 5-HT and in plasma corticosterone in response to changes in vibration intensity and vibration frequency.

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Material and Methods

The animals used were 32 male Wistar rats weighing 200–250 g (average 242 g). During the control period, the animals were lit from 8:00 to 20:00 and for the remaining time they were in darkness. The room temperature was fixed at 23 ± 2° C, and the rats were given diet and water *ad libitum.*

The apparatus for vibration exposure was an electromagnetic shaker (EMIC 513-A), coupled to an amplifier (Tachikawa TA-100), a function oscillator (NF-Model, E-1011) and a vibration meter (EMIC 505-D). The animals were subjected to vertical sinusoidal whole body vibrations for 240 min. In one experiment, the vibrations were with accelerations of 0.4G, 2.0G, and 5.0G and a vibration frequency of 20 Hz. In another, the vibration frequency was 5 Hz, 20 Hz, or 30 Hz, vibration acceleration being constant at 0.4G. The experiments were all carried out between 9:00 and 13:00. Rats were divided into eight groups; each group consisted of four rats. Four groups were used in the acceleration changing experiment (1 group served as control) and another four groups in the frequency changing experiments (1 group served as control). Throughout the experiments the exposed and control animals were kept individually in wiremesh cages in the prone position.

The animals were killed by decapitation immediately after their subjection to a vibration experiment. Blood was collected in a heparinized beaker and the brain was carefully removed from the cranium, blotted and chilled, and was kept in deep freeze (−80° C) until the 5-HT and 5-HIAA contents were determined. Brain 5-HT was determined fluorometrically (Bogdanski et al. 1956) after purification using an Amberlite CG-50 column (Karasawa et al. 1975). Brain 5-HIAA was determined by the double column method using Sephadex G-10 and QAE Sephadex A-25 columns (Karasawa et al. 1974). Plasma corticosterone was measured by a fluorometric method (Guillemin et al. 1959).

The significance of differences between values was examined by Student's *t*-test. To investigate the relationship between the changes of brain 5-HT and plasma corticosterone the Spearman correlation coefficient was used.

Results

Vibration Acceleration and Plasma Corticosterone

The levels of plasma corticosterone are shown in Fig. 1. In this condition, the vibration frequency was constant at 20 Hz and acceleration was changed from 0.4G to 5.0G. When the control group was compared with the vibration exposed group, the plasma corticosterone levels were significantly elevated in the 0.4G and 2.0G exposed groups ($P < 0.05$) and greatly elevated in the 5.0G exposed group ($P < 0.01$). The differences between the 0.4G and 5.0G groups ($P < 0.01$), and between 2.0G and 5.0G ($P < 0.01$) were statistically significant.

Vibration Frequency and Plasma Corticosterone

Figure 2 shows plasma corticosterone levels when the vibration frequency was changed from 5 Hz to 30 Hz, the vibration acceleration being kept constant at 0.4G. Compared with the control, each group exposed to vibration showed a significant increase ($P < 0.05$), but the levels were almost the same grade at each frequency.

Vibration Acceleration and the Brain Content of 5-HT and that of 5-HIAA

Figure 3 shows the effect on brain 5-HT and 5-HIAA when the vibration was accelerated from 0.4G to 5.0G. In each experimental group the levels of 5-HT were significantly higher than that in the control group ($P < 0.01$). As the vibration acceleration was increased, the 5-HT content tended to increase.

The mean value of the brain 5-HT content of the 5.0G group was 1.9 times as much as that of 2.0G group. The increase in 5-HT content was remarkable between these two groups. Similarly, the levels of 5-HIAA were elevated in each exposed group compared with the control, but to different extents than those of 5-HT. The levels of 5-HIAA at

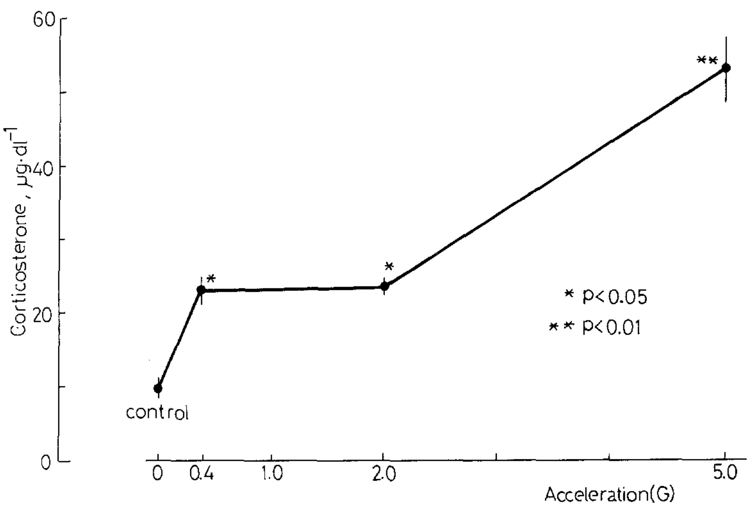

Fig. 1. Effect of acceleration on plasma corticosterone level. Frequency was constant with 20 Hz for 240 min. Each group represents a mean ± SEM of four rats

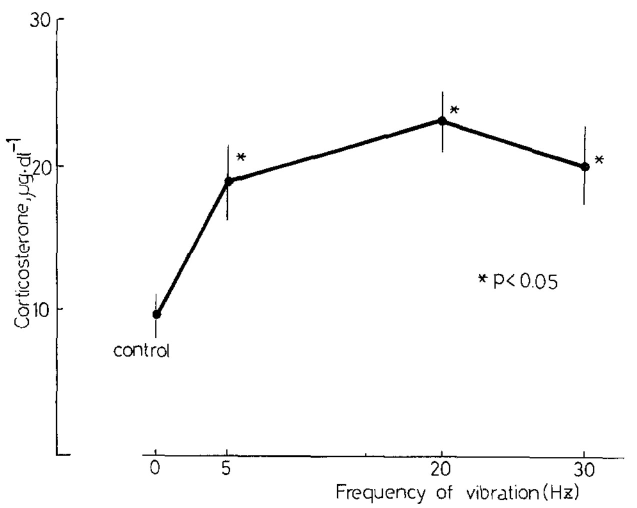

Fig. 2. Effect of frequency on plasma corticosterone level. Acceleration was constant with 0.4G for 240 min. Each group represents a mean ± SEM of four rats

vibration exposure of 2.0G and 5.0G were almost the same.

Vibration Frequency and the Content of Brain 5-HT and that of 5-HIAA

Figure 4 shows the change in content of 5-HT and that of 5-HIAA with changes in vibration frequency. Compared with the control values, both 5-HT and 5-HIAA were significantly elevated ($P < 0.05$) at the frequency of 20 Hz.

The Correlation Between the Content of Brain 5-HT and Plasma Corticosterone Level

The correlation coefficients are shown in Table 1. When the vibration acceleration was changed while the frequency was held constant, the correlation coefficient between brain 5-HT and plasma corticosterone levels was 0.93, which was statistically significant ($P < 0.01$). On the other hand, when frequency was changed with constant acceleration, the correlation coefficient was 0.58 ($P < 0.05$).

Discussion

1. Plasma Corticosterone and Whole Body Vibration

It is well established that the pituitary-adrenocortical system plays an important role in maintaining biological homeostasis against various stimuli. There

Table 1. Correlation coefficient between brain 5-HT and plasma corticosterone under the acceleration changing and frequency changing condition $n = 16$

	Changed acceleration	Changed frequency
Correlation coefficient between 5-HT and corticosterone	0.93**	0.58*

* $P < 0.05$, ** $P < 0.01$

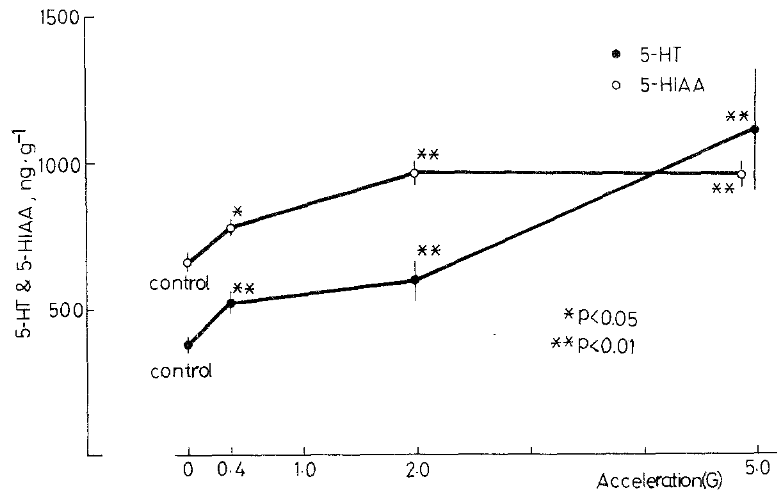

Fig. 3. Effect of acceleration on brain 5-HT and 5-HIAA levels. Frequency was constant with 20 Hz for 240 min. Each group represents a mean ± SEM of four rats

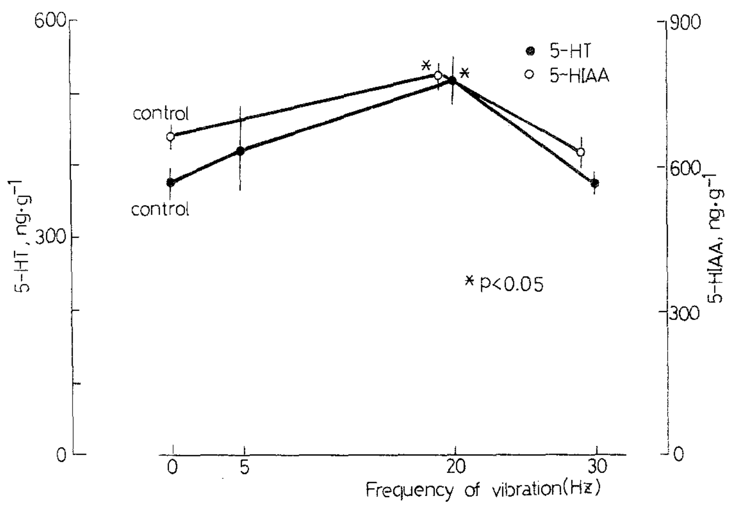

Fig. 4. Effect of frequency on brain 5-HT and 5-HIAA levels. Acceleration was constant with 0.4G for 240 min. Each group represents a mean ± SEM of four rats

are some reports of the effects of vibration stress on homeostasis, including that of Sugawara et al. (1972) on the effects of whole body vibration. Their finding that the level of serum corticosterone was raised as the level of acceleration was raised is in agreement with our study. They also observed significant increases in levels of serum and adrenal corticosterone at a frequency of 5 Hz. Another report was of changes in serum 17-OHCS during exposure to a low frequency of around 5 Hz (Blivaiss et al. 1965). These results agree with the report that the low vibration frequency of 4–8 Hz is important, based on the observation of blood circulation in human finger tips (Coermann et al. 1965), of blood pressure and blood flow in the dog (Edwards et al. 1972), and on the analysis of complaints of unpleasant feelings in humans during exercise (Grether 1971). However, in our observations of the effects of vibration frequency, low vibration frequency did not always have much effect. Plasma corticosterone levels were elevated significantly during subjection to 5 Hz, 20 Hz, and 30 Hz compared with the control, but there was no perceptible difference between each vibration exposed group. Indeed, in our study, when the vibration acceleration was as low as 0.4G it affected the rats equally, and no clear differences could be seen between the groups among different frequencies. From these results, it is suggested that the effects due to resonant frequency will not appear during low intensity vibrations because of the weakness of the stimulus.

2. Brain 5-HT and Whole Body Vibration

The presence of 5-HT in the mammalian brain has long been recognized (Twarog and Page 1953). Its concentration varies in different brain structures, and it is thought to function as a synaptic transmitter (Dahlström and Fuxe 1964, 1965). Although functions have been widely reported, no study of the relations between whole body vibration and levels of brain 5-HT has been reported hitherto.

Here we have paid attention to the adrenocortical system, which is known to be a sensitive index of physiological responses to stress, and to the 5-HT content of the brain. A marked change in 5-HT content of the brain has been found to occur during subjection of the whole body to vibration with a dose (vibration intensity)-response (change in brain 5-HT) relationship. Both 5-HT and 5-HIAA were especially elevated following subjection to a vibration frequency of 20 Hz. This finding indicates the functional activity of the 5-HT system containing neurones in the brain. The first resonant point with whole body vibration occurs in the head near to 20 Hz (Okada 1958). As this report is based on observation of the human body, and the resonant frequencies at various parts of the rat body are now little known, it is impossible to compare it directly with our result. On the other hand, our findings differ from the marked responses detected at 5 Hz in rat serum and adrenal gland corticosterone (Sugawara et al. 1972), our responses of 5-HT and 5-HIAA in rat brain being marked at 20 Hz. Further investigation seems to be required to elucidate this discrepancy. Furthermore, we found that both 5-HT and 5-HIAA increased as the vibration acceleration was increased. The elevation of 5-HT with the increase of vibration acceleration was more linear than that of 5-HIAA, and indicates that 5-HT release is more sensitive than 5-HIAA to acceleration. When the vibration acceleration was changed from 2.0G to 5.0G, the elevation of 5-HT greatly exceeds that of 5-HIAA. This suggests a change in metabolism, in short, the reproduction rate of 5-HT being more than that of release with high levels of acceleration.

3. The Relationship Between the Levels of Plasma Corticosterone and Brain 5-HT

The roles of amines in the brain, and of the hypothalamus in particular, in the regulation of the pituitary-adrenocortical system remain controversial. Norepinephrine, dopamine and 5-HT may have distinctive roles, and could be excitatory or inhibitory (Kumeda et al. 1974; Van Loon et al. 1971; Abe and Hiroshige 1974). With particular regard to 5-HT, its introduction into the septal area of the hypothalamus has been reported to cause an acute rise in plasma corticoid levels (Krieger and Krieger 1970). Our finding of a correlation between the changes of brain 5-HT and plasma corticosterone levels with increasing acceleration of whole body vibrations is consistent with a role of central 5-HT in the regulation of the pituitary-adrenocortical system, particularly since, in another study (Ariizumi and Okada, Br J Ind Med, in press), we observed the elevation of 5-HT in only two regions of the brain, the hypothalamus and the cerebellum.

In summary, with the increase of vibration acceleration the level of 5-HT in the brain increased parallel to that of plasma corticosterone. From these results, we conclude that brain 5-HT, especially in the hypothalamus, plays an important role in the promotion of pituitary-adrenocortical function.

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