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INFLUENCE OF STATIC LOAD ON HUMAN BODY

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ABSTRACT

The effects of a prolonged standing posture on human body have been studied. The subjects standing for 100 minutes on four strain gauge plates for force measurement, were asked to distribute the body weight evenly over each plate. The force measurements were taken, EEG was recorded, and the function of maintaining concentration (TAF) was tested.

Fluctuations in the distribution of the body weight over the force plates were divided into two types: type A, a higher amplitude with slow waves, and type B, a lower amplitude with rapid waves.

In type A, the action potentials from the gastrocnemius muscles decreased with time, and the correlation between the left and right electromyograms was high. In type B, there was no consistent relationship between the left and right and correlation was low. Type B was taken to be the case in which the stretch reflex loop functioned effectively.

The force on the force plates for keeping the balance of the body in a standing posture tended, with time, to concentrate on the predominant foot.

The results suggest that a standing posture alone, without work, is not always a big stress factor, as the increase in the alpha waves and no change in TAF indicated.

Recent development of science and technology has widely changed the form of industrial labour. There are jobs which especially require keeping a certain working posture continuously for a long time. We therefore studied the effect of a prolonged standing posture on the human body.

SUBJECTS AND METHODS

The subjects were eight healthy male students, who maintained a standing posture for 100 minutes on four strain gauge plates for force measurement. The subjects were asked to distribute the body weight evenly over each plate, and the forces on the plates were continuously measured (Fig. 1). In addition, the subjects' brain waves from the parietal part of the subject were recorded with monopolar leads and the electromyograms were taken from the left and right gastrocnemius muscles with surface leads. The function of maintaining concentration (TAF)[5] was tested before and after the static load of standing.

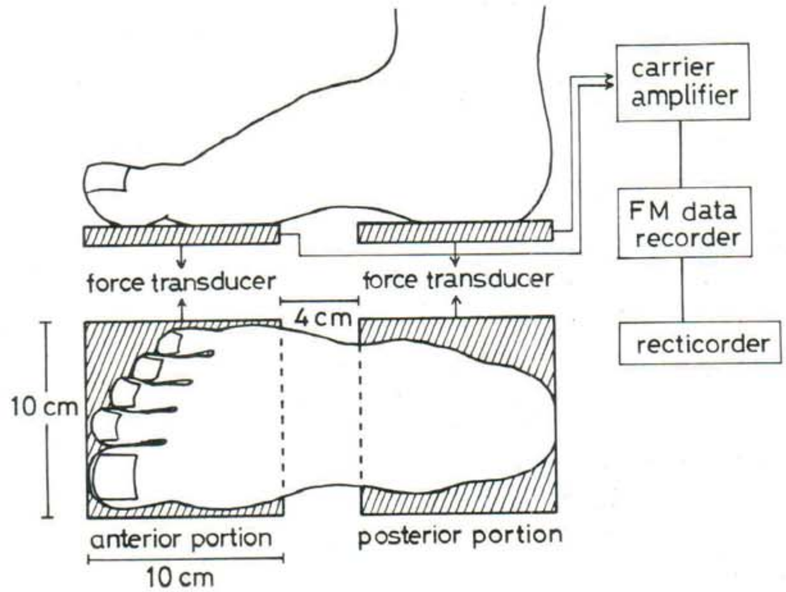

FIG. 1 – Block diagram of the force plate.

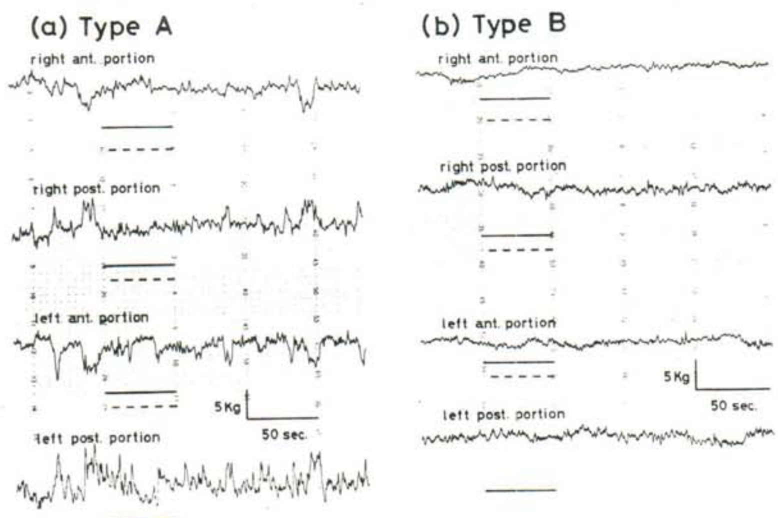

FIG. 2 – Fluctuations of the body weight recorded from the force plates in a standing posture.

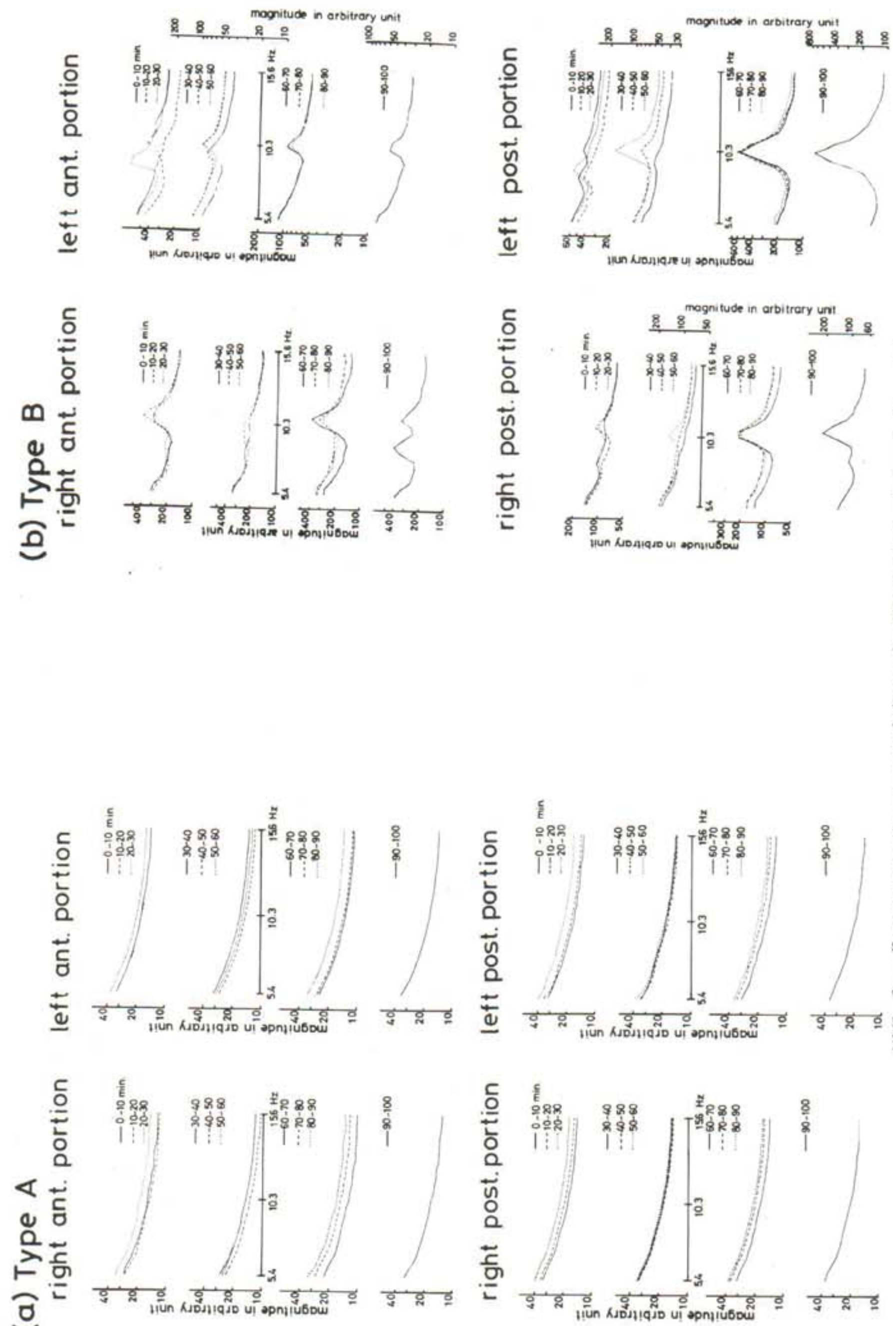

FIG. 3 — Power spectra converted from the fluctuation of the body weight.

RESULTS

Fluctuations of the distribution of the body weight over the force plates were divided into two types: type A, a higher amplitude with slow waves shown in Figure 2 (a), and type B, a lower amplitude with rapid waves shown in Figure 2 (b).

In Figure 3, the fluctuations of the distribution of the body weight were converted into a power spectrum by the Fourier analysis. Type A shown in Figure 3 (a), converted from Figure 2 (a), indicates that the power decreased gradually from 5 Hz or less to 15 Hz, and this tendency did not change with time. This was true for all the four portions: the left, right, anterior and posterior. In type B shown in Figure 3 (b), converted from Figure 2 (b), the power reached its peak at about 10 Hz, and the powers at all wave frequencies including that of the peak increased with time. This was observed with all the four portions, although the values of the peaks were different.

Figure 4 indicates the sequential changes in the rate (%) of average value of the 10-second integrals in each 10-minute calculated from the action potential of the gastrocnemius muscle compared with that of the first 10-minute. Figure 4 (a), which relates to the subject (type A) from Figure 2 (a), shows that both the rates of the left and right decreased with time almost parallelly. The correlation of the muscular action potential between the left and right is significant with a correlation coefficient of 0.83. All other cases belonging to type A showed a significant correlation with a correlation coefficient of 0.7 or higher. Figure 4 (b), relates to the subject (type B) from Figure 2 (b) and shows that there is no

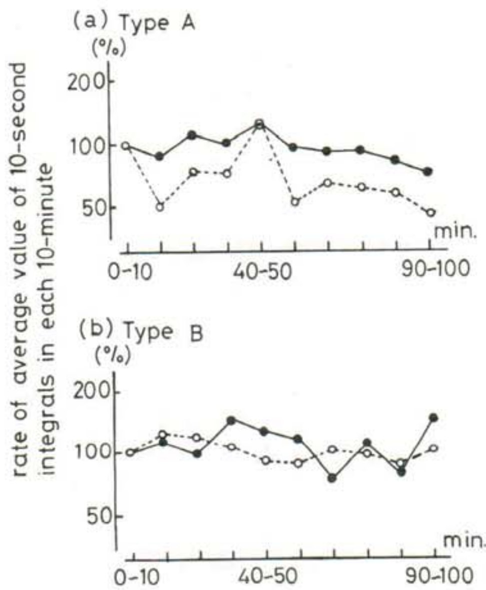

FIG. 4 – Sequential changes of gastrocnemius muscular action potential in a standing posture. Solid circles: right side, open circles: left side.

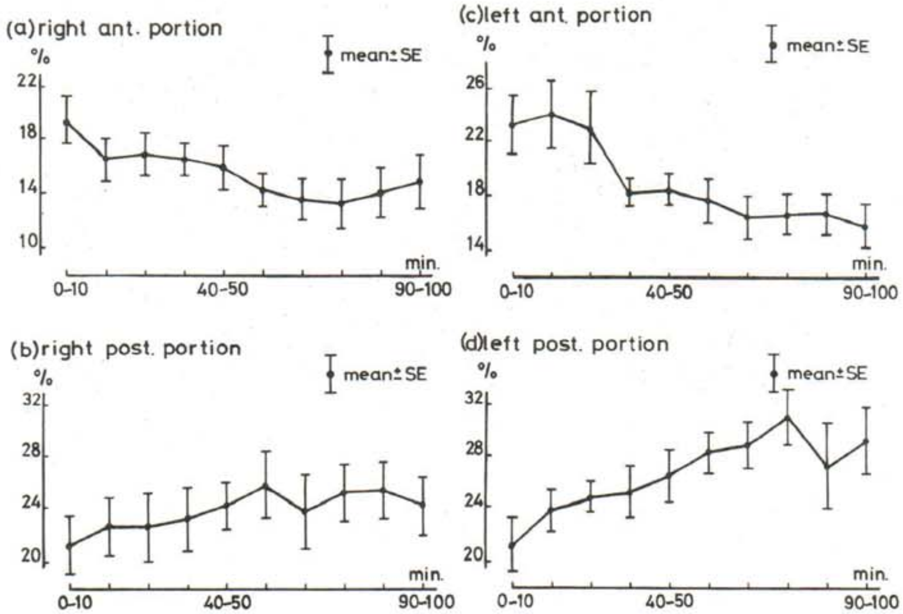

FIG. 5 – Most frequently occurring value of the body weight.

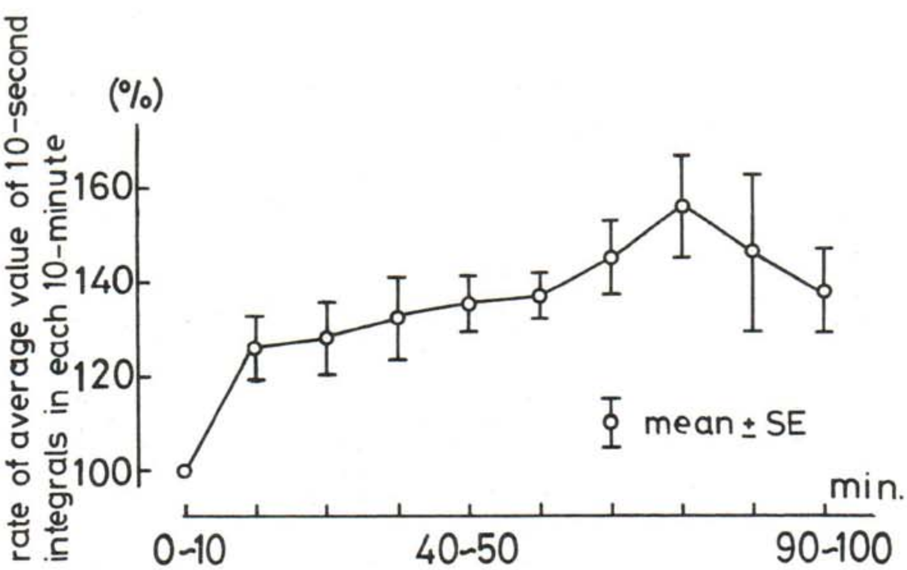

FIG. 6 – Sequential changes of alpha wave (EEG) in a standing posture.

consistent relationship between the left and right with a correlation coefficient of 0.14. All other cases relating to type B also showed no correlation with a correlation coefficient of 0.3 or lower.

Figure 5 indicates the distribution of the body weight over the force plates in a standing posture for 100 minutes. The most frequently occurring value of the body weight distributed over the right side in each 10-minute decreased gradually at the anterior portion and increased gradually at the posterior portion, while over the left side it decreased significantly at the anterior portion after 30 minutes of standing and increased significantly at the posterior portion after 40 minutes of standing.

Figure 6 shows the sequential changes in the rate (%) of average value of the 10-second integrals in each 10-minute calculated from the amplitude of the alpha waves compared with that of the first 10-minute. Significant increases were seen at all times of standing in comparison with the first 10-minute.

Figure 7 shows the changes in the function of maintaining concentration (TAF). TAF-L and TAF-D did not show any significant decrease after 100 minutes of standing, contrary to our expectations.

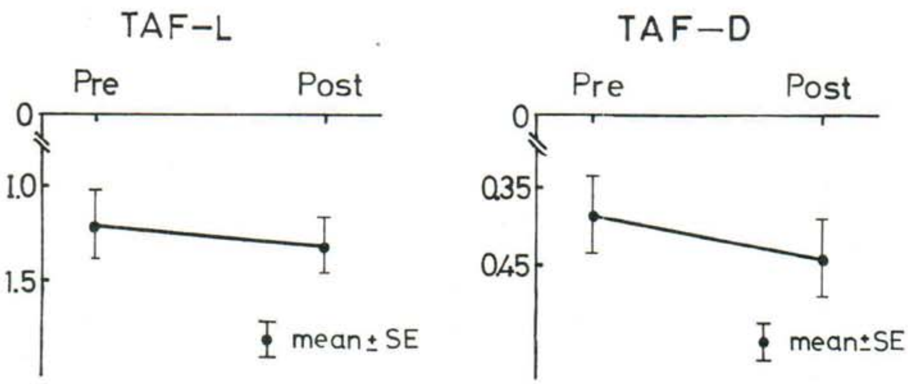

FIG 7 – Changes of TAF.

DISCUSSION

Maintaining a certain posture for a long time requires a continued static voluntary muscular action. Generally, in normal muscular movement rapid waves appear with a peak of 8 to 12 Hz caused by isometric muscular contraction. They are called "physiological tremor"[1]. It is recognized that the fluctuation of the distribution of the body weight in a standing posture, which is synonymous with Mori's "postural tremor"[3] is included in the category of "physiological tremor".

In this experiment, it was presumed that in keeping a standing posture for a long time the body weight might be distributed evenly over the four force plates, left and right, anterior and posterior, and that the force on each plate might vary around the value of one quarter of the body weight. However, the most frequently occurring value of the distribution of the body weight indicated that the force for keeping the balance of the body in a standing posture, repeating a delicate movement along the axes of anterior-posterior, left-right, and diagonal, concentrates on the predominant foot.

It is a very interesting fact that the fluctuations of the distribution of the body weight in a standing posture can be divided into two types, that is, type A with no special peak in power, and type B with a peak of 8 to 12 Hz.

In type B, the wave frequencies at the peak in power spectrum and the fire frequencies of stationary and non-stationary discharges from muscular motor units are synchronized after a short time[4]. It is assumed that the physiological tremor is brought about by this synchronization, in the control mechanism of which the Renshow cell takes part.

As for the central nervous system, the stretch reflex loop is closely related to the static state of maintaining a standing posture. In general, it is considered that the stretch reflex loop functions as a negative feedback loop and participates in voluntary muscular movement. It is therefore presumed that the stretch reflex loop works to reduce the internal disturbance in its network[2], as a result, the physiological tremor arises.

In our experiment, type B is considered as a case in which the stretch reflex loop works effectively, because the muscular action potentials of both sides did not change greatly with time and the correlation coefficient between the left and right was so small. On the contrary, type A is presumed to be a case in which special individual factors may inhibit the functioning of the stretch reflex loop.

An increase of the alpha waves may be caused by the reduction of afferent nervous impulses in a continued static state. The results of the TAF test suggest that a standing posture without work for a long time does not cause apparent physical or mental fatigue[6].

CONCLUSIONS

The present experiment was carried out to study the effects of maintaining a standing posture for a long time on human body. Fluctuations in the distribution of the body weight were divided into two types: type A, a higher amplitude with slow waves, and type B, a lower amplitude with rapid waves.

Expressing the fluctuations in the power spectrum, type A showed a gradual lowering in power in proportion to the increase of the wave frequency and no change with a lapse of time. Type B showed a peak in power at 8 to 12 Hz and the power at all frequencies increased with time.

In type A, action potentials from both the left and right gastrocnemius muscles, almost simultaneously, decreased with time, and the correlation coefficient between the left and right was high. In type B, there was no consistent relationship between the left and right with a low correlation coefficient.

The force on the force plates for keeping the balance of the body in a standing posture tended to concentrate on the predominant foot with a lapse of time. The alpha waves increased significantly with time. There was no significant change in TAF.

These results suggest that the standing posture alone, without work, is not always a big stress factor to human body, as the increase in the alpha waves and absence of change in TAF indicated.

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