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Role of the Sensation of Foot Pressure Distribution in Standing Position

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1 Introduction

The pressure sensation from the soles would play a important role in biped human for maintaing and controlling a posture[4]. This sensation is presumably integrated with other sensory informations. However, integration aspect is less well known. There are several reports on the sensory information from the soles, and various research methods have been developed recently. These are to use polyuretane[7] and shotgun-ball[5] to have the subject stood on them, and to use synthetic cryo-air transpire[1] and cold water[6] to cool the sole. These researches have hardly focussed on the position but the stability of posture. We investigated a role of foot pressure sensaton in standing position, by increasing the pressure sensation from hind or front part of foot soles.

2 Method

The subjects were nine male univesity students whose ages were 18 to 19 years. The pressure sensation was increased by standing on a floor that many columns (diameter 5mm and height 1.2mm) projected at interval of 3mm in an oblong area of 45×210mm. The projection and pull of columns were controlled by a hydraulic pump (Figure 1).

At first, the columns were projected rapidly and randomly under the heel or metatarso-phalangeal parts in foot soles while the subject was standing with eyes closed (Figure 2), and the anteroposterior position of the center of foot pressure (CFP) picked up with the force plate and the EMGs of m. tibialis anterior (TA) and m. gastrocnemius medialis (GCM) picked up with bipolar surface electorodes were observed with particular reference to the temporal course.

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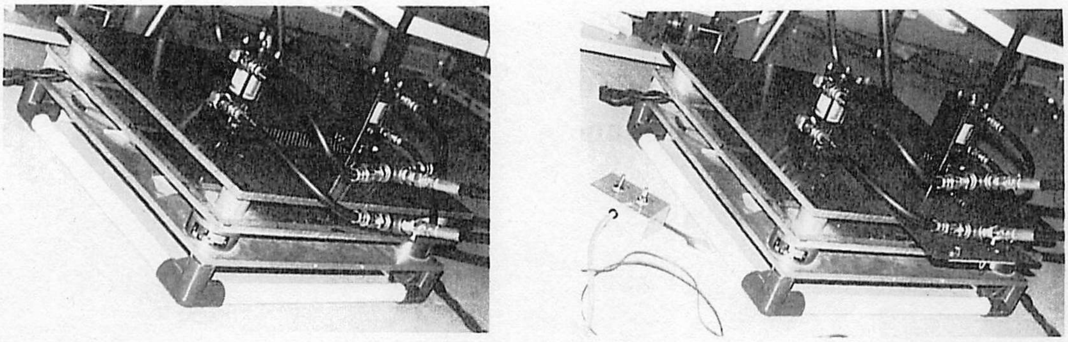

FIGURE 1. Apparatus for foot pressure increment (left figure) and a flat board having a thickness of 1.2mm (right figure).

Secondaly, the subjects standed with eyes closed for 30 seconds on a force plate having floors of five types : ① flat, ②projecting the colums under the metatarsophalangeal joint and ③ the heel part, and ④ putting a flat board having a thickness of 1.2mm under the metatarsophalangeal joint part and ⑤ the heel part. The standing in each floor condition was repeated 5 times with inserting a rest sitting on a chair for one minute. The standing position was evaluated by the mean of anteroposterior position of the CFP. The CFP -position was analyzed using the A/D conversion data for 10-30 seconds. The resolution and sampling time of A/D conversion were 0.2mm and 50 msec. That position was shown in relative distance from the hindmost position of the heel, regarding the foot length as 100%. All statistical analysis was calculated with 5% significance level.

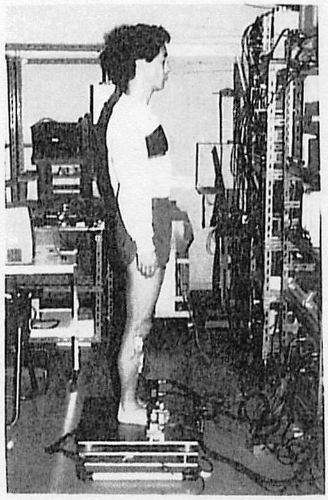

FIGURE 2. Standing with eyes closed.

3 Result

After the columns were projected while the subject was standing on the floor, the CFP -position was slowly moving forward in the stimulus to the metatarsophalangeal part or backward in the stimulus to the heel part in the course of about 2-5 seconds, and in the same time course the activity of GCM increased in the metatarsophalangeal part stimulus and decreased in the heel part stimulus (Figure 3). On the other hand, TA was continually inactive.

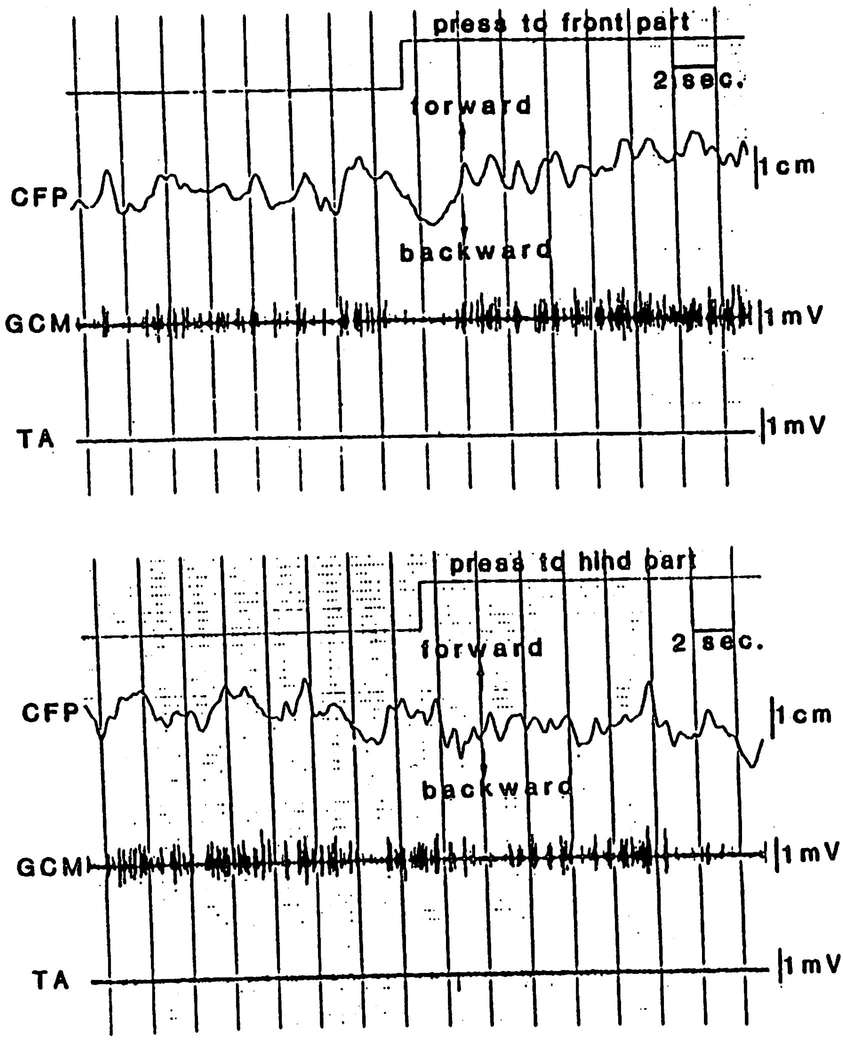

FIGURE 3. Typical records of CFP and EMGs of GCM and TA.

The CFP-positions in floor conditions of ①, ④ and ⑤ were 45.1±5.87%, 45.5±5.80% and 43.9±6.07%, respectively (Figure 4), and these differences were insignificant. The positions for floor conditions of ② and ③ were 48.3±5.70% and 40.6±5.52% (Figure 5), and these positions showed significant differences against the positions of ①, ④ and ⑤. This indicated that the CFP-positions changed toward the direction that the pressure sentation increased.

4 Discussion

Okubo et al.[5] gave the stimulation to the whole foot soles by use of boards with inlaid

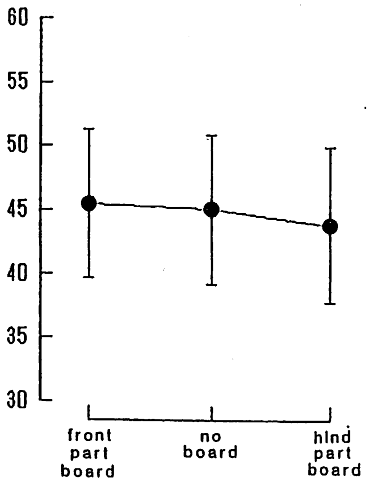

FIGURE 4. Mean position of CFP on boad and no boad.

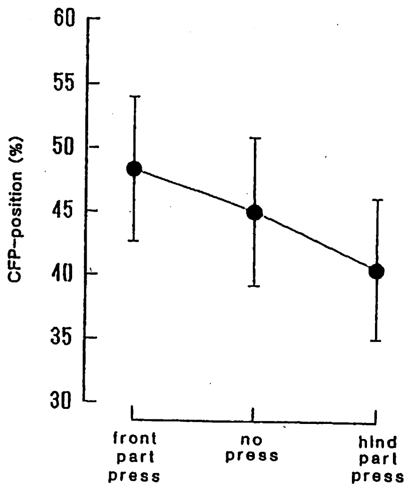

FIGURE 5. Mean position of CFP in conditions: press to front part and hind part and no press.

shotgun balls similar to our method. They found that the discharge from the tibial nerve fibers markedly increased when the stimulus was given, as compared to no stumulation. Futhermore, they found that M-and H-wave charge were negligible despite different degrees of stimulation. From these results they surmised that the increase in plantar mechanoreceptor input information participated in higher central nervous system control mecanisms rather than the spinal level control system. The slow changes of CFP-position and GCM activity in our study support this view. In many other previous studies which increased and decreased the pressure information from foot soles were reported that the pressure information participated in low frequency ingredient of CFP fluctuation[1),2),8),9),10)]. It is conceavable that this result is due to same ground as above mentioned.

Futhermore, we obtained the result that the CFP-position changed toward the heel or metatarsophalangeal joint which the pressure sensation increased. The change range was about 3% of foot length and in which range m. tibialis anterior was inactive. We previously reported that m. tibialis anterior was active in the backward CFP position beyond about 34% (mean value) of foot length from the hindmost point[3)]. This position is more behind than the hindmost position obtained in this study. These results probably suggest that anteroposterior position in stance is not decided by balance of pressure sensations of metatarsophalangeal joint and heel parts in sole, but by matching the stmatosensory information (deep sensation from the dorsally situated muscles, such as m. soleus and m. gastrocnemius) to the sensation of foot pressure distribution.

5 Conclusion

We investigated a role of sensation of foot pressure distribution in stance with eyes closed. The pressure sensation was increased by standing on a floor that many columns (diameter 5mm and height 1.2mm) projected at interval of 3mm in an oblong area of 45× 210mm. The CFP-position changed toward the heel part or metatarsophalangeal joint one that the pressure sensation increased. That changing time was about 2-5 seconds. On the other hand, when the subjects standed on the floor putting a flat board having a thickness of 1.2mm under the above mentioned foot sole parts, the CFP located at same position as the flat floor.

These results presumably suggest that anteroposterior position of CFP in stance with eyes closed is not decided by the balance of pressure sensations of metatarsophalangeal joint and heel parts in sole, but by matching the deep sensation to the sensation of foot pressure distribution.

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