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Research article

Postural control during transient floor translation while standing with the leg and trunk fixed

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HIGHLIGHTS

- We investigated CNV and postural muscle activity before floor translation with joint fixation.
- Postural adaptation to the disturbance with fixation occurred rapidly.
- CNV peak amplitude was increased with the adaptation.
- A high correlation was found between CNV peak and start times of triceps surae activity.
- Attention would be focused on the sensory information related to the triceps surae activity.

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ABSTRACT

Postural movement was restricted above the ankle, and contingent negative variation (CNV) and postural muscle activity were investigated during a transient floor translation (S2) 2 s after an auditory warning signal (S1). For 13 healthy young adults, the joints of the knee, hip, and trunk were fixed using a cast brace. Under no-fixation and fixation, a set of 10 translations was repeated at least 4 times, and center of pressure in the anteroposterior direction (CoPap), posterior postural muscle activity of the body (elector spinae (ES), biceps femoris (BF), gastrocnemius (GcM) and soleus (Sol)), and late CNV at Cz were analyzed in the initial two sets (initial set) and last two sets (late set). In the no-fixation, CoPap forward displacement after S2 gradually decreased. In the first trial of the fixation, it had significantly increased, and then rapidly decreased across subsequent trials. CNV peak amplitude was largest in the late set of the fixation. The activity of postural muscles increased just before S2 and in the late set the start time showed high correlations with CNV peak time in all muscles (ES ($r = 0.88$), BF (0.92), GcM (0.80), and Sol (0.89)) under the no-fixation, but exclusively in the GcM (0.84) and Sol (0.88) under the fixation. When postural control was restricted mainly to the ankle, attention would have been focused mainly on processing sensory information from the triceps surae just before the floor translation.

1. Introduction

To investigate dynamic postural control during standing, many researchers have used a transient floor translation task [1]. Anticipation of the disturbance and postural preparation for floor translation is an important factor in this task [2]. The frontal lobe, including the prefrontal cortex, supplementary motor area, premotor area, and primary motor area, is closely involved in these functions [3], but the contribution of these regions to dynamic postural control remains incompletely understood. Therefore, we investigated the activation of these brain regions, measuring contingent negative variation (CNV) from a warning signal (S1) to a transient floor translation (S2) [4,5]. CNV is the negative slow potential obtained by averaging the electroencephalogram (EEG) recorded between S1 and S2 [6]. The late component of CNV reflects the motor preparation process and anticipatory attention directed to S2 [7,8]. Late CNV shows a peak just before S2, and it has been suggested that this CNV peak corresponds to a peak of anticipatory attention and/or onset of attentional shift to objects other than S2 [4,9].

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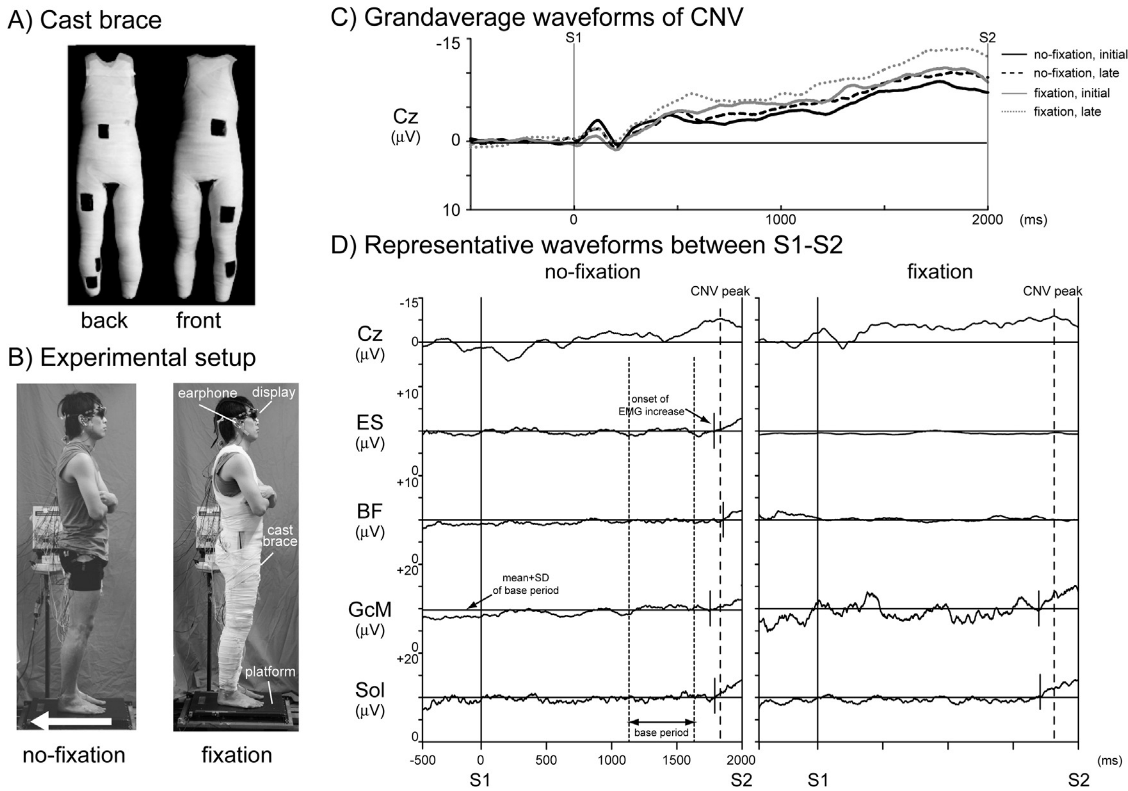

Fig. 1. Experimental setup and waveforms.

The triceps surae (TS) is activated in response to a backward floor translation [1]. We have demonstrated that there is a continuous (about 400 ms duration) increase in TS activity from around the CNV peak to S2 or a transient (50–100 ms duration) increase around the time of the CNV peak followed by backward displacement of the center of pressure in the anteroposterior direction (CoPap) [4]. After adaptation to such floor translation, the onset time of the muscle activity increase changed to have a significant correlation with the CNV peak time, suggesting that the peak related to the attentional allocation to the sensory information from TS just before the disturbance [5,10]. However, there were inter-individual differences in postural muscle activity after the floor translation. For some subjects, activation was observed in the thigh and/or trunk muscles [1]. Also, just before S2, some subjects showed no increase in TS activity around the CNV peak. These findings suggest that sensory information from the trunk and thigh muscles might contribute to the preparation for the postural disturbance. Thus, we created a task condition in which postural control must be focused on TS, by the joint fixation above the ankle. After sufficient adaptation with the fixation, attention will be focused to TS, and thus, we will be able to demonstrate a close relation between the CNV peak time and the onset time of the preparatory activation of TS. Such joint fixation also allows many researchers to apply the inverted pendulum model with a single axis at the ankle [11].

In this study, a cast brace that immobilized the joints in the leg and trunk except the ankle joint was made for each subject, and the relation between CNV and postural muscle activity before postural disturbance was investigated. The following working hypotheses were tested: After sufficient adaptation to the postural disturbance with joint fixation; (1) postural control would be focused on TS, and (2) a high correlation would exist between the CNV peak time, and the onset time of the preparatory activation of TS.

2. Methods

2.1. Subjects

Subjects were 13 healthy adults (7 men, 6 women). Mean (standard deviation (SD)) age, height, weight, and foot length (FL) were 22.4 (3.5) years, 164.3 (7.4) cm, 56.8 (6.6) kg, and 24.3 (1.1) cm, respectively. No subject had any history of neurological or orthopedic impairment. Informed consent was obtained from all subjects following an explanation of the experimental protocols, which were approved by our institutional ethics committee.

2.2. Apparatus and data recording

A force platform (FPA34; Electro Design, Japan) was used to measure CoPap. The CoPap signals were sent simultaneously to one computer (PC9801BX2; NEC, Japan) to determine CoPap position online and to another computer for analysis offline. The former received CoPap data via an A/D converter (PIO9045; I/O-Data, Japan) at 20 Hz with 12 bit resolution and could generate a buzzer sound when CoPap was within ±1 cm of the required position. CoPap position was calculated as the percentage distance from the heel in relation to FL (%FL). The platform was fixed to a handmade table that was movable horizontally in an anteroposterior direction by a linear motion guide actuator (SKR4610A-0290-1-1001; THK, Japan) with a computer-controlled electric motor (SANMOTION MODEL No. PB PBBR604; SANYO DENKI, Japan). Direction, velocity, and amplitude of the platform movement were adjusted by the motor. S1 was an auditory stimulus delivered via earphones with a 2000 Hz frequency, 35 dB intensity above the threshold and 50 ms duration. S2 was a backward floor translation.

Ag–AgCl cup electrodes (8 mm diameter) for recording EEG were placed on the scalp at Fz, Cz, and Pz in accordance with the international 10–20 system, and referenced to linked ear lobes.