Electromyographic responses in lower leg muscles evoked by a sudden drop of support surface during human walking and standing

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Introduction
It is well recognized that afferent feedback allows the animal automatically to correct for disturbances that occur during real walking. Limited information is available, however, concerning human corrective reactions to disturbances especially that occur during stance phase. To investigate the corrective reactions to an abrupt change of ground condition during human gait, we developed a new experimental device that makes it possible to drop a supportive surface. In the present study we investigated electromyographic (EMG) responses in lower leg muscles to a sudden drop of supportive surface during walking and standing. The purpose was to clarify 1) whether spinally mediated short latency responses are induced in lower leg muscles following the drop of support surface, and 2) whether there is any task-specificity in the induced responses.

Methods

Subjects were twelve neurologically normal adults (24+5 yrs, 172+3 cm, 61+6 kg) who had no neurological disorder. A specially designed movable platform was used to drop a support surface (duration: 30 ms, distance: 10mm) and was incorporated into a 5 m-long walkway (Fig.1). The support surface was located so that the fourth step landed on it, and could be dropped at a given timing by a computer. To measure reactions to the drop of supportive surface, perturbations were induced 1) while the subjects were walking on the walkway (walking trial) and 2) while standing still on the supportive surface (standing trial). In the walking trial the support surface was dropped at the early stance phase, and the perturbation trials were randomly mixed with no-perturbation trials to reject any effect of anticipation. EMG activities of the soleus, the lateral gastrocnemius, the medial gastrocnemius (MGAS), the tibialis anterior (TA) of both legs, and ground reaction forces were recorded with a sampling frequency of 500 Hz. Mean rectified EMG amplitude (MREMG) was calculated in each 10 ms time bin from the trigger signal and the peak value was evaluated to quantify the response magnitude. The
corresponding MREMG amplitudes during no-perturbed walking and standing were subtracted from those during perturbed trials.

**Results**

Fig. 2 shows a typical example of EMG responses to the drop of support surface during walking and standing still. Short latency EMG responses following impact of the drop (\(< 50\) ms) were consistently observed in all perturbed leg muscles during the walking, while no muscle except TA showed such responses in the contralateral leg. The short latency responses to the drop were also observed during the upright standing. However, there were large inter-muscular differences in the amplitude of the short latency responses.

Fig.3 summarizes means and standard errors of MREMG values in each muscle for the walking and standing trials. The most striking result was that the response amplitude of MGAS was markedly increased (\(p < 0.05\)) during the walking compared to that during the standing, whereas no large changes in the EMG responses were observed in the other ankle extensor muscles. Another marked result was that in both walking and standing trials EMG responses in TA were generally greater than the other muscles, except MGAS in the walking trial.
Discussion

The present results revealed that the short latency, possibly spinal reflexes were induced by sudden drops of support surface during both walking and standing. Similar responses have been reported recently by Schillings et al. (1999), in which the leg in swing phase was obstructed with an obstacle during treadmill walking. They suggested that the collision impact of hitting an obstruct elicits the spinal stretch reflex during walking. Taken together their result into account, it was conceived that the observed short latency responses in this study were most likely mediated by the spinal monosynaptic reflex pathway originating from muscle spindles. Further, the markedly greater MGAS response specifically during the walking suggested that the excitability of this pathway was selectively augmented in the ankle extensor muscles at least during the early part of the stance phase. It has been reported that cutaneous reflex responses during the stance phase of walking was selectively augmented in MGAS by Duysense et al. (1996). They have suggested that the augmented response was related to the functional role of MGAS during this phase. In the present study, little EMG responses were observed in the contralateral ankle extensor muscles and greater responses in both sides TA during walking. The greater TA responses were observed during standing as well. The co-activation of antagonistic muscles shortly after the impact of drop might be the first line of defensive response as Schilling et al (1999, 2000) suggested. In summary, our results showed that the EMG responses to drop of supportive surface in the ankle extensor muscles are task- and phase-dependent, but the responses in TA are generally higher. In other words the inter-muscular pattern of short latency responses as a whole was highly task-specific, although neural mechanisms underlying these responses are remained to be answered by future studies.

References