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CONTROL OF THE LOWER LEG MUSCLES DURING STANCE ON INCLINED MOVING SURFACES

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SUMMARY
The purpose of this study is to investigate the influence of inclined support surface on a postural strategy with changes in platform translation frequency. This work assessed experimentally the contribution of central and peripheral mechanisms in the control of posture under different combinations of inclined support surface translations. No differences between the correlation between center of pressure and medial gastrocnemius activity were found, despite of different support surface inclinations. This result suggests that the mechanisms to control stance have an important central component. The delay times between CoP and MG were negative, and these times at 0.2Hz were significant larger than those of 0.8Hz. It indicates that the motor command to MG precedes the displacement of CoP.

INTRODUCTION
Although it seems easy to maintain the standing posture, human bipedal stance is unstable: a large portion of the body mass is located high above a small base of support. Therefore, sophisticated mechanisms of the postural-control system are required for maintaining upright posture and reject the natural perturbations occurring in everyday life. Healthy humans are able to select distinct strategies depending on task requirements. According to previous studies, during upright bipedal posture two primary coordination modes have been identified through a range of perturbations and control conditions. One coordination mode is named ankle strategy. In this case, the postural system can be viewed as an inverted pendulum with motion only about the ankle joint. A second mode includes a hip strategy where the motion at this joint preserves stability against postural perturbations [1]. These strategies can be combined depending on the task requirements. Buchanan et al. [2] have examined the effect of frequency of sinusoidal platform translation on postural movement. They have demonstrated that for slow translation frequencies subjects can remain in upright stance and ride the platform with little motion about the ankle, knee and hip joints. For fast translation frequencies, a different postural pattern emerges, with the head and upper trunk fixed in space relative to the moving platform with extensive motion about the ankle, hip and knee joints. They suggested that fixing the head in space is important to remove the visual scene oscillation produced by the translating support surface, thus allowing vision to aid in high frequency postural control. Therefore, human upright posture is maintained by a combination of peripheral and central neural mechanisms. The central nervous system integrates complex afferent and efferent control signals, based on body orientation and motion information, which are provided by the vestibular, visual and somatosensory systems. In this context, Sasagawa et al. [3] investigated the active stabilization mechanisms on an inclined surface during quiet standing. As a result, they found that electromyography (EMG) activity changed as a function of support surface conditions, indicating that increased (decreased) passive contribution required less (more) extensor torque generated by active muscle contraction. Taking these results into account and considering that standing on inclined surfaces is common during daily life activities, it is important to assess the effect of support surface condition on postural strategy. Previous studies have mainly examined linear motion of body segments and, in some cases, under a limited range of experimental perturbations. For example, the surface inclination has not been manipulated systematically with changes in platform translation frequency. Therefore, the purpose of this study is to investigate the influence of inclined support surface on a postural strategy with changes in platform translation frequency. This work assesses experimentally the contribution of central and peripheral mechanisms in the control of posture under different combinations of inclined support surface translations.

METHODS
The experimental apparatus consisted on a parallel link mechanism with six degrees of freedom (MB-150, COSMATE, JAPAN) that moved the support surface equipped with a force platform (9286A, KISTLER, JAPAN) and that can have different inclinations around the medio-lateral axis. An optical motion measurement system (HWK-200PT, Motion Analysis, USA) synchronized with an EMG equipment (MEG-6108, NIHON KOHDEN, JAPAN and band width is 15Hz to 1kHz) was used to record the motion of the eight healthy male subjects (age: 22.9±1.6 [year], height: 171.1±5.1 [cm], weight: 64.0± 1.7[kg]) that volunteered for the experiments. None of them had previous history of motor disorders. Informed consent was obtained from all participants prior to their participation. The experimental procedure was approved by the local ethical committee. Subjects stood on the support surface with three different inclinations: Toe Up (TU), Level (LV), and Toe Down (TD) with eyes closed. The support surface was translated sinusoidally in the antero–posterior direction at

two different frequencies: 0.2 and 0.8 Hz. Marin et al. [4] reported that postural coordination patterns switched from in-phase to anti-phase mode from 0.5 to 0.6 Hz. So we selected 0.2 Hz as slow translation frequencies and 0.8 Hz as fast translation frequencies. The support surface translation was 100 mm peak to peak for 70 sec. Center of pressure (CoP) in anterior –posterior direction was calculated from the force plate data. For all subjects, EMG activities from the right lower leg muscles; TA and medial gastrocnemius muscle (MG), RF, BF were recorded. Measured EMGs were rectified and filtered. The CoP and EMGs were recorded at 1000 Hz sampling frequency. Reflective markers attached to the platform and subject. Markers were attached to the following landmarks: top of head, acromion, pelvis, great trochanter, lateral condyle, external condyle, and platform. Center of mass (CoM), ankle and hip joint angles were calculated from the coordinates of reflex markers measured by the motion capture device. The sampling frequency of motion capture device was 200 Hz. The cross-correlation function (CCF) between CoP and EMG of the MG was calculated for each condition. To test statistically the difference among the support surface conditions, one-way ANOVA with repeated measures along with a post hoc analysis (Scheffe test with $P<0.05$) were used.

RESULTS AND DISCUSSION

Fig.1 shows a typical examples of the CoM and CoP displacements along with the electromyogram of the muscles considered (MG) recorded during platform at 0.2 Hz and 0.8Hz under EC condition. Fig.2 shows the results of CCF analysis among CoP and MG. There were high positive correlations. The delay times of between CoP and MG were negative in both translational frequencies and all surface conditions. Regardless of surface conditions, the delay times in 0.2Hz were significant longer than those of 0.8Hz. There were no significant differences in surface conditions.

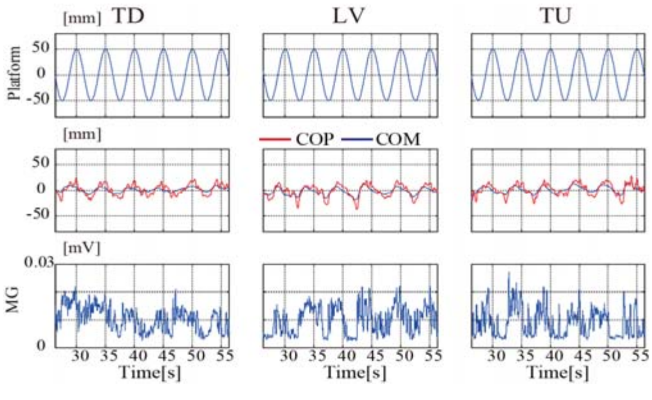

Figure 1 Examples of the CoM and CoP displacements along with the EMG of the Medial Gastrocnemius (MG) recorded during 0.2Hz platform translations and under three different support surface inclinations (TD: Toe Down, LV: Level and TU Toe Up).

Fig.1 and Fig.2 show that EMG activity of MG is a very high correlation with the CoP or the body CoM. It could be hypothesized that this is a clear result of a peripheral control of stance. In this respect, the correlation between the trajectory of the CoP and the EMG activity could be explained by a simple stretch-reflex mechanism. In order to test this idea, the configuration of the body on the platform during stance was modified to stretch or slack certain leg muscles. If the control mechanism is purely peripheral the different muscle lengths should alter the responses and the correlation between EMG activity and CoP trajectory.

However there were no significant differences between the correlation coefficients. This result suggests that the mechanisms to control stance have an important central component. The delay times between CoP and MG were negative, and they were significantly larger at 0.2Hz than those at 0.8Hz. It indicates that the motor command to MG precedes the displacement of CoP. The motor command precedes CoP displacement in order to compensate the delay between the neural signals and the muscle force as well as neural transmission latency from the central nervous system.

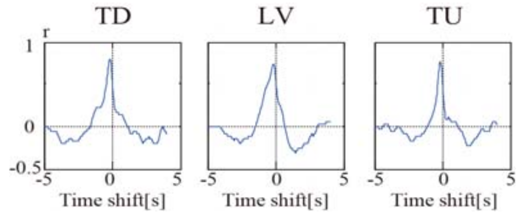

Figure 2: Examples of the normalized cross-correlation function (CCF) ensemble averaged for 7 cycles.

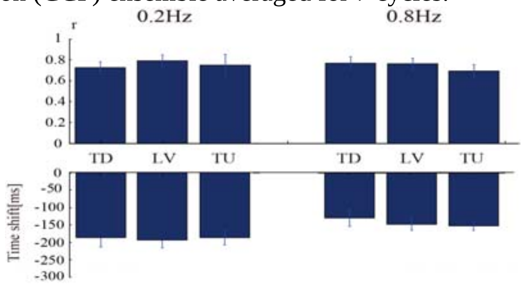

Figure 3 Group means of the cross-correlation analysis between COP and MG

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