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SHORT COMMUNICATION

Age-Related Changes in Postural Responses to Backward Platform Translation

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Summary

The aim of the study was to investigate age-related changes in postural responses to platform translation with 3 various velocities. We focused on the influence of linear velocity using the smoothed profile of platform acceleration (till 100 cm.s^{-2}). Eleven healthy young (20-31 years) and eleven healthy elderly (65-76 years) subjects were examined. The subjects stood on the force platform with their eyes closed. Each trial (lasting for 8 sec) with different velocity (10, 15, 20 cm.s^{-1}) of 20 cm backward platform translation was repeated 4 times. We have recorded displacements of the centre of pressure (CoP) and the EMG activity of gastrocnemius muscle (GS) and tibialis anterior muscle (TA). The results showed increased maximal values of CoP responses to the platform translation. There was also observed a scaling delay of CoP responses to platform translation with different velocities in elderly. The EMG activity of GS muscle during backward platform translation was of about similar shape in both groups during the slowest platform velocity, but it increased depending on rising velocity. EMG activity of TA was not related to the platform velocity. Early parts of postural responses showed significant co-activation of TA and GS muscles of elderly. It is likely that elderly increased body stiffening in order to help their further balance control.

Key words

Age • Postural control • Leg muscle activity • Postural strategy

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Small balance instability visible in elderly during quiet stance (Abrahámová and Hlavačka 2008) can affect also dynamic postural responses to unpredictable support surface translation (Tokuno *et al.* 2006). The influence of age on muscular responses (Henry *et al*. 1998, Brown *et al*. 2001, Müller and Redfern 2004) and kinematic responses to platform translation (Tokuno *et al*. 2010) was documented.

Healthy subjects with no sensory impairment maintain balance in response to the horizontal support surface perturbation by employing quick active hip rotation and trunk stabilization in vertical position. Younger adults likely rely more on hip, or better to say upper torso strategies than older adults with increased magnitude of postural responses (Müller and Redfern 2004, Szturm and Fallang 1998). Some data showed that elderly rather use body stiffness as a protective strategy to reduce sway in postural response to perturbation. In response to surface roll tilts, they activate trunk stiffness (Allum *et al*. 2002). It was also observed that elderly activate hip stiffness in response to lower leg muscle vibration during stance (Abrahámová *et al.* 2009). Stiffening means activation of both: agonist muscle and antagonist muscle around the ankle in response to platform translation (Woollacott 1993, Tokuno *et al.* 2006, 2010). Increased velocity of platform translation results into increased muscular contribution in the control of the trunk, while demand on distal musculature decreases with change in platform speed (Bothner and Jensen 2001).

In this study, we investigated age-related

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changes in the postural responses to backward linear platform translation with three velocities. Postural responses to platform translation depend on both: acceleration and velocity. Our intention was to analyze mainly the influence of platform velocity; therefore the minimized acceleration with smoothed profile was used to diminish its influence. The smoothed profile of acceleration has a cosine bell time course without short impulse of acceleration which occurs during non-smoothed profile.

Eleven healthy elderly (senior group; 6 males and 5 females; mean age 71.1±3.6 years, range 65-76 y) and eleven healthy young subjects (junior group; 5 males and 6 females; mean age 24.5±3.1 years, range 20-31 y) participated in this study. They declared neither neurological, orthopedic, nor balance impairments. They gave their informed consent in agreement with the Declaration of Helsinki. The study was approved by the local Ethics Committee.

We focused on the somatosensory and vestibular system where we can expect slight sensory impairment due to age. Therefore, the influence of vision was removed. Subjects stood on the force platform with their eyes closed, head forward, and stance width of approximately 10 cm, constant for each subject during each trial. Subjects were instructed to maintain balance without stepping. The experiment consisted of 3 trials with different velocities (10, 15 and 20 cm.s^{-1}) of 20 cm backward platform translation using the smoothed profile of platform acceleration (till 100 cm.s^{-2}).

A single perturbation per trial was administered. Each trial lasted for 8 seconds and translation of platform started 1s after the onset of recording. Each of these three conditions were repeated 4 times and randomized to avoid prediction and habituation.

The centre of pressure (CoP) of subjects in upright stance was measured by the custom made force platform with direct output of CoP, with 3 force transducers inbuilt, and equipped with automatic weight correction. The CoP displacements in the anterior-posterior direction were sampled at frequency of 1000 Hz. Postural responses of each subject were adjusted that their mean value of CoP positions for 1 s before platform translation onset was considered as zero. The maximal magnitudes of four CoP responses during each platform velocity for each subject were averaged.

The EMG activity of medial gastrocnemius (GS) and tibialis anterior (TA) muscles were recorded by DAB-Bluetooth device (Zebris Medical GmbH, Germany) with surface electrode pairs (Noraxon dual electrode) with an electrode diameter of 1 cm and inter-electrode spacing of 2 cm. The EMG signals were measured on a left limb, amplified and sampled at 1000 Hz. No attempt was made to calibrate EMG records on the absolute scale, but amplifier gains were set once and maintained throughout each experimental session. The EMG records were normalized for each subject based on the maximum EMG responses evaluated during the fastest platform velocity (20 cm.s^{-1}) through all conditions prior to averaging of juniors and seniors. Changes in magnitude of EMG responses to the platform translation were determined from individual trials as the integrated area between the rectified EMG (IEMG) response and average baseline EMG 100 ms prior to the platform translation. The IEMG was calculated for interval of 1300-1800 ms (Fig. 1). It means 300-800 ms after onset of platform translation (1000 ms).

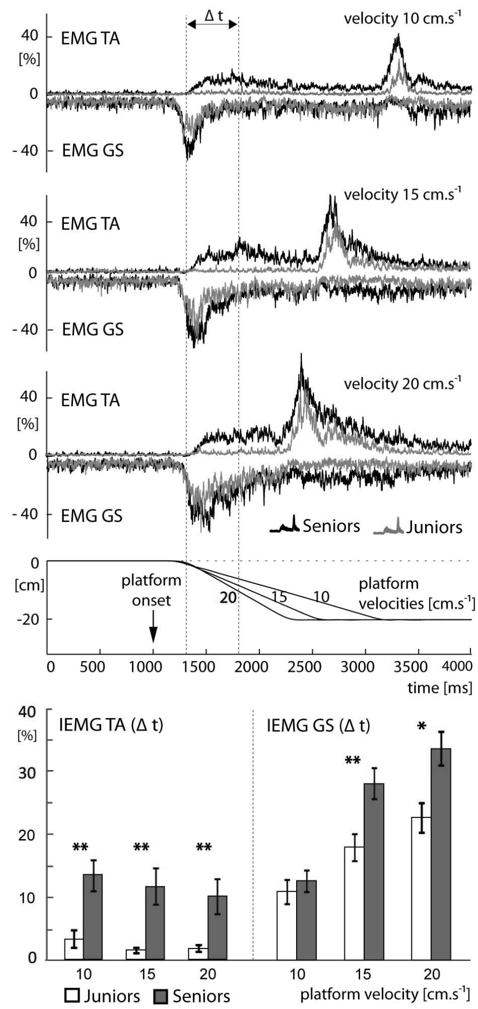

Fig. 1. Group average of EMG activity of TA and GS muscles related to 3 different velocities of platform translation in juniors (shadow) and seniors (black). Values of integrated EMG (IEMG TA, IEMG GS) are presented at the bottom as mean ± SEM.

The IEMG data and CoP maximal values for three platform velocities and two groups of subjects (seniors and juniors) were compared using two-way, repeated measures ANOVA; *post hoc* analysis was performed using Newman-Keuls procedures ($\alpha=0.05$).

The CoP displacement differences between the platform velocities of 10 cm.s^{-1} and 20 cm.s^{-1} were analyzed using Student's *t*-test for both age groups individually. The point was marked as a start of reactions scaling when the statistical significance appeared. Vertical lines in the CoP traces represent these start points in Fig. 2. The scaling delay is the difference between these start points in juniors and seniors.

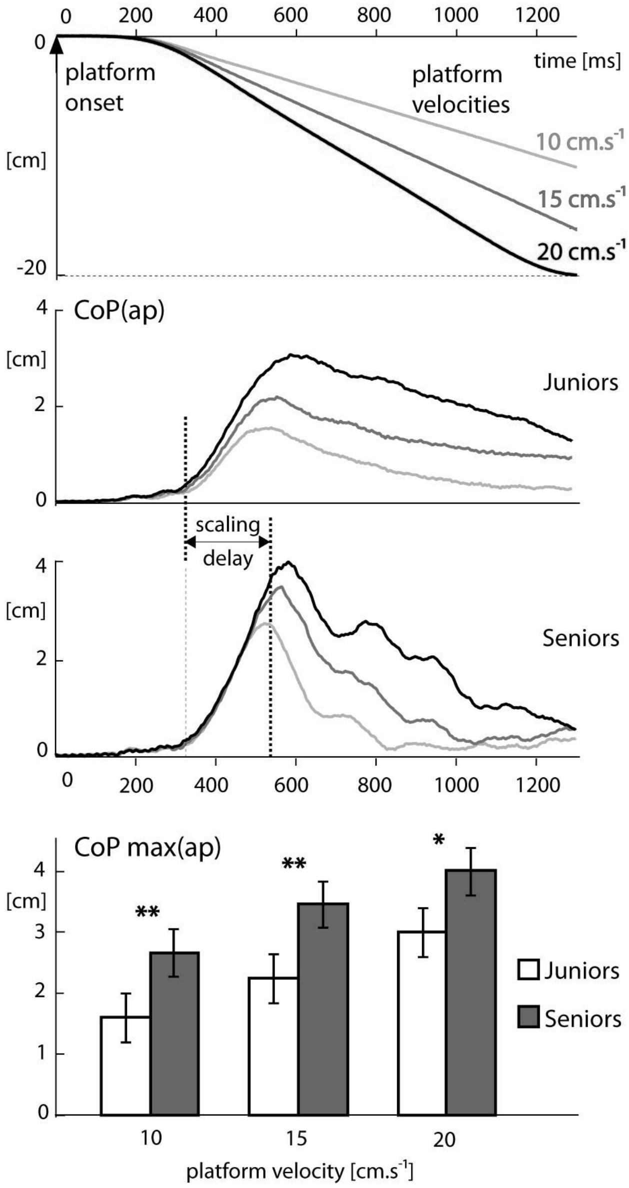

Fig. 2. Group average of CoP(ap) responses to 20 cm backward platform translation with 3 different velocities. Maximal values of CoP(ap) displacements (CoP max) of juniors and seniors are presented at the bottom as mean ± SEM.

Figure 2 shows that 20 cm backward platform translation induced body tilt forward with changes of the CoP position in anterior-posterior direction which started with a faster increase of magnitude. The maximal value of CoP response depends on the velocity of platform translation and is more noticeable in elderly.

The maximal CoP displacement in anterior-posterior direction measured during the platform translation with different velocities in junior group was 1.72±0.13 cm at velocity of 10 cm.s^{-1}, 2.31±0.18 cm at velocity of 15 cm.s^{-1} and 3.08±0.23 cm at velocity of 20 cm.s^{-1}. In senior group, the maximal CoP displacement was 2.73±0.24 cm at velocity of 10 cm.s^{-1}, 3.53±0.28 cm at velocity of 15 cm.s^{-1} and 4.07±0.37 cm at velocity of 20 cm.s^{-1}. The values are expressed as mean and standard error of mean.

Two-way repeated measures ANOVA, that compared maximal CoP displacement between two age groups in three different velocities of platform translation (Fig. 2) showed significant effect of age ($F=10.84$, $p=0.0035$) and also significant effect of the translation velocity ($F=70.42$, $p<0.0001$).

Statistically significant differences in CoP displacement between platform velocities of 10 cm.s^{-1} and 20 cm.s^{-1} appeared 328 ms after translation onset in juniors and 538 ms after translation onset in seniors. It means that a scaling delay of about 210 ms was observed in elderly (Fig. 2).

Horizontal translation of the support surface induced body tilt forward with related EMG activity of GS and TA muscles. The average EMG activity of TA and GS muscles measured during the platform translation with different velocities is presented in Fig. 1. The EMG activity of GS muscle during backward platform translation was of about similar shape in both groups during the slowest platform velocity, but it increased depending on rising velocity. EMG activity of TA was not related to the platform velocity. Early part of the postural response to the platform translation showed significant co-activation of TA and GS muscles of elderly.

Two-way repeated measures ANOVA of IEMG GS showed significant effect of age ($F=14.50$, $p=0.0003$) and velocity ($F=25.54$, $p<0.0001$). The significant effect of age ($F=32.22$, $p<0.0001$) was also observed in IEMG TA. There was no statistically significant effect of the translation velocity ($F=1.18$, $p=0.3147$).

The main purpose of this study was to investigate age-related changes in postural responses to the backward support surface translation with velocities of 10, 15 and 20 cm.s^{-1}. CoP displacements were increased in this range of platform velocities in both: juniors and seniors. We found out that maximal CoP responses to the platform translation were more increased in seniors in comparison to juniors (Fig. 2). Our findings are in agreement with previous study of Szturm and Fallang (1998).

We also observed a scaling delay of CoP responses to three different velocities of platform translation in elderly. These results demonstrate that statistical difference between CoP responses to platform velocity of 10 cm.s^{-1} and 20 cm.s^{-1} occur in elderly later than in young subjects. In this way elderly showed a scaling delay related to platform velocity of about 210 ms. It is likely that effect of body stiffening in the early part of postural responses in elderly may produce some delay in scaling of platform velocity. It is known that the earliest part of EMG bursts and also CoP responses are likely to be scaled primarily to the platform translation velocity (Diener *et al.* 1988).

We observed significant differences in EMG activities of both TA and GS muscles to the backward platform translation between juniors and seniors, except of EMG of GS during the slowest platform velocity. In the early part of postural responses to the backward platform translation EMG activity of TA muscle showed a minimal level in young subjects. In contrary, increased EMG activity of TA muscle in the same part of postural responses occurred in elderly. It means that significant co-activation of TA and GS muscles during early part of the postural responses to the support surface translation was showed in elderly. This fact about antagonist-agonist co-activation is in agreement with previous findings (Woollacott 1993, Tokuno *et al*. 2006). It is obvious that older adults activated stiffening around the ankle in response to platform translation. In previous studies body stiffening was observed not only in ankle joint (Tokuno *et al*. 2010 − Fig. 5) but also in hip joint (Abrahámová *et al*. 2009) or trunk (Allum *et al*. 2002). According to these studies, it is likely that body stiffness was present not only in ankle joint as we observed, but also in a hip level. Furthermore, it looks like that older people compensated balance disturbances related to platform motion using body segment stiffening. Younger adults likely relied more on hip / upper torso strategies (Müller and Redfern 2004) in this condition. As a possible reason for activation of stiffening could be the fear of falling in anticipation of perturbation (Maki *et al*. 1991, Allum *et al*. 2002). In accordance with study of Tokuno *et al.* (2006), the active role of the distal antagonistic muscles is not so clear, but a co-activation strategy (stiffening) as a response to the translation may be potentially effective in order to improve balance control.

Conflict of Interest

There is no conflict of interest.

Acknowledgements

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