Length changes in Achilles tendon during upright standing in various balance conditions for young and elderly adults
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SUMMARY
This study was designed to assess length changes in Achilles tendon by measuring movements of the myotendinous junction (MTJ) of the gastrocnemius in young and elderly adults during quiet upright standing in various balance conditions. The MTJ moved proximally during forward sways and distally during backward sways in all age groups and balance conditions. These movements likely indicate lengthening of the Achilles tendon during forward sways and shortening during backward sways. Interestingly, greater length changes in Achilles tendon were associated with greater fluctuations in postural balance.

INTRODUCTION
Ageing has been associated with a decrease in the postural control capacity (1) and increased risk of fall (2). Decrease in maximal force (3) and ability to control force fluctuations (4) of the ankle plantarflexor muscles have recently been suggested to impair balance capacity. In addition to skeletal muscle changes, alterations in tendon properties also contribute to muscle weakness (5), and may influence the balance capacity as more compliant tendon has been associated with lower torque steadiness (6).

The aim of this study was to compare changes in Achilles tendon length in young and elderly adults during four balance conditions.

METHODS
Eight young (21-35 yrs; 5 women) and eight older adults (67-88 yrs; 5 women) participated in this study. Surface electromyogram (EMG) was recorded from the soleus, gastrocnemius medialis and lateralis, and tibialis anterior during the four following balance conditions: rigid surface/eyes open (REO); rigid surface/eyes closed (REC); foam surface/eyes open (FEO); foam surface/eyes closed (FEC). These balance conditions were assumed to induce differences in visual and proprioceptive inputs. Each balance condition was repeated 3 times for about 1 min by trial during which subjects were asked to keep upright standing as steady as possible with knee extended and arms along the trunk. Data for center of pressure (COP) were collected by means of a force platform (Model OR-6, AMTI, USA). Four COP measures were computed from the force platform signals for a 20-s epoch: COP path length, antero-posterior standard deviation of the COP (COP-sd), antero-posterior maximal velocity of the COP (COP-vel); antero-posterior maximal amplitude of the COP (COP-max).

During the postural tasks, B-mode ultrasonography was used to determine the MTJ displacements of the gastrocnemius for changes in the moment on the x-axis of the force platform (antero-posterior moment, Mx) that crossed the mean value of Mx (computed for a 20-s epoch) with an amplitude greater than one standard deviation. Five forward sways and 5 backward sways were computed for each condition. In addition to the change in the position of the MTJ, the rate of change of the MTJ and the ratio between changes in MTJ and Mx were computed for each measured sway.

RESULTS AND DISCUSSION
The COP path length, COP-sd, COP-vel and COP-max increased from the REO to FEC and were greater in elderly adults than in young adults (age x balance condition, P < 0.05)(Table 1).

The EMG activity of the plantarflexor muscles also increased from the REO to the FEC condition, with a greater increase for old adults (age x balance condition, P<0.001).

In all subjects, the MTJ moved to a more proximal position during forward sways and to a more distal position during backward sways (Figure 1) for the four balance conditions. The MTJ displacement increased (balance condition main effect, P<0.001) from the stable conditions (REO and REC) to the unstable conditions (FEO and FEC) for both forward and backward sways (Figure 1). Similarly, the associated changes for Mx increased from REO to FEC conditions (balance condition main effect, P < 0.001), but were greater for old than young adults (age main effect, P < 0.02). The MTJ displacement relative to changes in Mx increased for both groups and sway directions (balance conditions main effect, P < 0.01) from REO to FEC, likely reflecting the greater elongation of the tendon with the increase in muscle activation. In addition, the rate of change in MTJ position was positively associated with the COP path length and the COP-sd ($r^2 > 0.74$) suggesting that the greater the movement of the MTJ, the greater the fluctuations in balance.

These data are in agreement with the paradoxical muscle movement observed for the plantarflexor muscle during upright standing (7). In contrast with the common idea that the calf muscles were stretched during forward sway, Loram and colleagues (2004) have shown that muscle shortened during forward sways and lengthened during backward sways. The present results extent such observation to old adults and
unstable conditions (FEO and FEC). In regard with the greater tendon compliance reported in old adults (Narici et al. 2008), the absence of difference between young and elderly adults may be surprising. Further analyses are currently in process to highlight the influence of various parameters on Achilles tendon length changes during the postural tasks.

**CONCLUSIONS**

These preliminary data are consistent with the paradoxical muscle length change previously reported during upright standing. However, the present results extent such observation to old adults and to balance conditions in which visual and proprioceptive clues are altered. Moreover, the change in Achilles tendon length appears to be associated with the fluctuations in postural balance.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


**Table 1:** COP parameters (mean ± SD) for young and elderly adults in the four balance conditions. * Statistical difference (P <0.05) between young and elderly adults.

<table>
<thead>
<tr>
<th></th>
<th>COP-sd (cm)</th>
<th>COP-vel (cm.s⁻¹)</th>
<th>COP-max (cm)</th>
<th>COP path length (cm)</th>
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<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Old</td>
<td>Young</td>
<td>Old</td>
</tr>
<tr>
<td>REO</td>
<td>0.4 ± 0.2</td>
<td>0.4 ± 0.2</td>
<td>1.5 ± 0.6</td>
<td>2.0 ± 0.8*</td>
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<tr>
<td>REC</td>
<td>0.4 ± 0.1</td>
<td>0.4 ± 0.2</td>
<td>1.8 ± 0.3</td>
<td>2.2 ± 0.6*</td>
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<tr>
<td>FEO</td>
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<td>0.7 ± 0.2*</td>
<td>2.6 ± 0.4</td>
<td>3.7 ± 0.1*</td>
</tr>
<tr>
<td>FEC</td>
<td>0.9 ± 0.3</td>
<td>1.4 ± 0.2*</td>
<td>4.5 ± 1.0</td>
<td>7.3 ± 1.4*</td>
</tr>
</tbody>
</table>

**Figure 1:** Change in the MTJ position (relative to distal) during forward and backward sways for the 4 balance conditions, in young (filled bars) and old adults (open bars). REO: rigid surface/open eyes; REC: rigid surface/closed eyes; FEO: foam surface/open eyes; FEC: foam surface/closed eyes.