THREE-DIMENSIONAL TRUNK MOVEMENTS DURING TREADMILL WALKING AT DIFFERENT SPEEDS IN HEALTHY SUBJECTS.

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SUMMARY
The aim of this study was to assess the three dimensional (3D) movements of the trunk in young and older healthy subjects during walking on a treadmill with different speeds. The presented data contribute to the knowledge of trunk biomechanics during walking.

INTRODUCTION
The kinematics of the lower extremities during walking is well described in healthy subjects. The importance of the trunk and pelvis during gait has been mentioned already in the 50s [1]. Saunders et al. described rotation of the pelvis, tilting of the pelvis, flexion of the knee in stand phase, foot- and knee mechanics and the lateral shift of the pelvis as the six most important elements of the gait. These components are fundamental during the gait because they are necessary to create space for the swing leg and they decrease the movement of the body centre to save energy [2]. Although the control of the trunk is an important factor for locomotor efficiency, less attention has been spent to the movements of the pelvis and the trunk during locomotion, especially related to different speeds. This article presents data related to the 3D kinematics of the trunk in young and older healthy subjects during walking at different speeds on a treadmill.

METHODS
Healthy subjects aged between 20 and 30 years (group 1) and between 50 and 60 years (group 2) were recruited. The inclusion criteria for the volunteers were: a normal range of motion of the lower extremities and trunk, capability to walk on a treadmill and no history of lesions of the lower extremities or trunk in the last 6 months. Persons with orthopaedic or musculoskeletal deformations, osteoporosis and anomalies of the lower extremities or trunk were excluded from this study. Each participant completed a questionnaire on demographical, anthropometrical and medical data. The subjects walked at different speeds (1, 2, 3, 4 and 5 kmph) on a motorized treadmill (figure 1). A familiarization period of 4 minutes was introduced before starting the measurements at the different speeds. The recording time was 30 seconds. Kinematic electromagnetic tracking of the trunk and the pelvis was done using a Polhemus Liberty (@240Hz). Local embedded frames (X: anterior, Y: superior and Z: right) were constructed by means of anatomical markers on the sacrum and the right and left PSIS (posterior superior iliac spine) for the pelvis segment and on the sternum, C7 and the sacrum for the global trunk segment. The XYZ Cardan sequence was used for the rotation. The centre of mass of the trunk (COMt) was determined at 37%, measured from caudal (pelvis) to cranial (C7). Statistical analysis was done in PASW19 using a Repeated measures ANOVA and post hoc Bonferroni correction.

RESULTS AND DISCUSSION
In total 32 subjects (group 1: 15 subjects between 20 and 30 years old and group 2: 17 subjects between 50 and 60 years old) participated in this study. The characteristics of the participants are reported in table 1. All subjects completed the protocol like previously described.

<table>
<thead>
<tr>
<th>Group 1 (n=15)</th>
<th>male/ female</th>
<th>age (years) mean (range)</th>
<th>height (m) mean (range)</th>
<th>weight (kg) mean (range)</th>
<th>BMI (kg/m2) mean (range)</th>
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<tbody>
<tr>
<td></td>
<td>9/6</td>
<td>26.3 (21-30)</td>
<td>1.75 (1.58-1.85)</td>
<td>72.53 (54-85)</td>
<td>23.5 (20-25.9)</td>
</tr>
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</table>

The movements of the global trunk were analyzed in relation to the pelvis. There was a significant (p<.05) increase of the trunk rotation in relation to the pelvis with increasing speeds (figure 2). No significant differences were found in trunk

Figure 1: experimental design
anterior flexion and lateral flexion between the different speeds. Comparing the two groups of subjects, trunk rotation, anterior-posterior flexion and lateral flexion of the trunk in relation to the pelvis show significant differences. The amplitude of the lateral flexion of the trunk is higher in the older group (mean: 25.2°) compared to the younger group of subjects (mean: 9.1°) (figure 3). Also the amplitude of the anterior-posterior flexion of the trunk is higher in the older group (mean: 15.3°) compared to the younger group of subjects (mean: 6.4°) (figure 4). The amplitude of the rotation of the trunk is higher in the younger group (mean: 10.2°) compared to the older group (mean: 6.8°).

The lateral displacement of the COMt in space is not significantly different for the different walking speeds, only from 1 to 4 kmph the lateral displacement decrease significant (mean from 9.1cm with 1 kmph to 7.2cm with 4 kmph). In the antero-posterior direction a significant decrease of the displacement of the COMt in space has been found when increasing the walking speed (mean from 13.3cm with 1 kmph to 7.6cm with 5 kmph). The amplitude of the vertical displacement of the COMt in space is significantly higher with higher walking speeds (mean from 1.5cm with 1 kmph to 3.9cm with 5 kmph) (figure 5). Comparing the two groups there are significant differences in lateral and vertical displacements of the COMt in space. The younger group shows a significant higher vertical displacement of the COMt in space (2.8cm to 2.1cm) and a significant lower lateral displacement of the COMt in space compared to the older group (7.2cm to 8.6cm).

The amplitudes of the trunk movements during walking on a treadmill are small. During walking at a low speed the rotations of the trunk in relation to the pelvis and the vertical displacement of the COMt are smaller than during walking at a high speed. The antero-posterior displacement of the COMt is higher at low speeds than at high speeds. There is some contradiction in the literature concerning the trunk movements during slow and fast walking. Kavanagh [3] reported that walking at speeds slower than preferred primarily alters lower trunk accelerations in the frontal plane. Other studies presented that angular displacements didn’t change when walking slower than normal, and that walking faster than normal increases the trunk angle deviations [4]. In this study the group of older subjects showed more anterior flexion and lateral flexion of the trunk and more lateral movement of the COMt during walking, but less rotation of the trunk and less vertical displacement of the COMt in comparison to the younger group. It is reported in the literature that when young and older (mean age 71 year) subjects are compared, significantly greater trunk sway angles and velocities are found in older than in young subjects [4].

CONCLUSIONS
Control of the trunk during gait is important with two third of the body mass situated above the waist. We can conclude that: 1) with higher walking speeds the rotation of the trunk and the vertical displacement of the COMt increase and the antero-posterior displacement of the COMt decreases; 2) with higher age anterior flexion and lateral flexion of the trunk and lateral displacement of the COMt increase and trunk rotation and vertical displacement of the COMt decreases. The presented data contribute to the knowledge of trunk biomechanics during walking. This knowledge is clinically relevant taking into account the risk of fall problems in the elderly.

REFERENCES
3) Kavanagh J, J neuroeng rehab, 6:9-19, 2009