TORSION OF THE FOOT DURING A LATERAL JAB DESCRIBED USING A MODIFIED HELICAL AXIS APPROACH

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SUMMARY
Torsion of the foot defined as the rotation of the forefoot relative to the rearfoot in the frontal plane has been studied previously; however, the location of the axis of rotation is unknown. This study used a helical axis method to describe torsion of the foot during a lateral cutting movement. The mean helical axis lied centrally in the midfoot during a barefoot lateral jab. This information could be useful for building sport shoes that allow a natural movement of the foot.

INTRODUCTION
Torsion of the foot is defined as the rotation of the forefoot relative to the rearfoot in the frontal plane and occurs in the midfoot region. It has been described during different dynamic movements like running and cutting movements. The influence of sport shoes on the torsion range of motion has been studied previously; it was found that shoes reduce the maximal torsion occurring during a movement [3]. Sport shoes often contain a torsion element that allows torsion of the shoe but restricts unwanted movement in the midfoot like bending [4]. However, the appropriate positioning of the torsion bars is not described in the literature. It can be assumed that a torsion element in shoes should be located and oriented according to the location and orientation of the foot torsion axis so that the shoe does not force the foot into unnatural movements. A method to calculate the foot torsion axis has been described previously [2]. The purpose of this study was to describe the torsion axis location and orientation during the stance phase of a cutting movement.

METHODS
13 subjects (age: 25.8±3.1 years; height: 176.6±5.7 cm; weight: 71.9±6.6 kg) were recruited and gave informed consent. Inclusion criteria were no current lower extremity injuries or pain and ability to perform the movement task. The subjects performed seven maximal effort lateral jabs barefoot. Three retro-reflective markers were attached to each of the forefoot and rearfoot and their movements were recorded with eight Motion Analysis high-speed digital cameras operating at 240Hz. Simultaneously, the ground reaction forces were recorded with a Kistler force plate collecting at 2400Hz to determine foot-ground contact.

Matlab software was used to calculate the rotation axis of forefoot relative to rearfoot using a combined Euler angle and helical axis approach [2]. Flexion of the rearfoot relative to the forefoot about the metatarsal line was first calculated using Euler angles. This flexion was removed from the movement; then, the helical axis of the movement of the forefoot relative to the rearfoot was calculated. The torsion angle was calculated as the rotation around the helical axis projected onto the anterior-posterior axis of the rearfoot coordinate system.

RESULTS AND DISCUSSION
The mean torsion angle curve was similar to curves described in the literature [1, 5]. Maximal torsion occurred at around 75% of the whole stance phase and was 27°±5°. The main difference to previous reported data was that the foot landed in forefoot inversion of about 10° at the beginning of the stance while previous data reported an initial torsion of about 0°. However, previous data were entirely based on shod movements while this study had the subjects performing barefoot. It is assumed that in preparation of the landing the foot is actively put into forefoot inversion when performing a lateral jab barefoot.

![Figure 1: Average torsion angle curve (n=13)](image)

In order to compare the vertical and medio-lateral location of the helical axis between subjects, the location in the antero-posterior direction was set at a point in the midfoot 120 mm anterior from the origin of the rearfoot coordinate system. Table 1 shows the mean location and orientation and figure 2 gives a visual representation of the helical axes.

The vertical location was negative; therefore, the mean axis lied slightly underneath the reference system origin but still within the foot. In the medio-lateral direction the axis lied 6.4mm lateral to the origin of the reference system.

<table>
<thead>
<tr>
<th>Table 1: location and orientation of mean helical axis (n=13)</th>
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<td>Location [mm]</td>
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<td>orientation</td>
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<td>0.987±0.016</td>
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However, the standard deviations showed that the differences between subjects can be large (maximal difference between subjects: 26mm in vertical direction, 28mm in medio-lateral direction). The mean axis had its main orientation in the anterior-posterior direction (0.987). The component in the medio-lateral direction (flexion) was very small which is expected since the methodology aims to remove flexion around the metatarsal line. The fact that the axis was inclined in the sagittal plane indicates that some ab-/adduction is occurring during the movement.

CONCLUSIONS
The described method could be used to calculate the helical axis of the forefoot relative to the rearfoot without the influence of forefoot flexion as well as to calculate the torsion angle. The helical axis for a barefoot lateral jab was located centrally in the foot. It was oriented mainly in the anterior-posterior direction and had a small inclination in the vertical direction. It could therefore be approximated as the torsion axis. Such information could be used to construct torsion elements in shoes that allow a more natural movement of the foot in the shoe.

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REFERENCES