INTRODUCTION

Fractures at the femoral neck play an important role in morbidity and mortality among older adults [1]. Understanding the loading environment is a crucial factor for reducing the incidence of fracture at this site [2,3]. The loading at the femoral neck can be measured or estimated using forces, moments, and stresses [3]. Based on previous studies, both sagittal and frontal hip moments are greater in stair ascent than descent [4], but it is unknown if stresses in the femoral neck have a similar pattern. In this study, the stresses at the superior and inferior sites of femoral neck during stair ascent and descent were estimated by applying a series of models. These femoral neck stresses were compared to the peak loading from sagittal and frontal plane internal hip moments.

METHODS

Five male and five female adult subjects (age: 59 ± 6.1 yrs; body mass: 68.90 ± 10.30 kg; height: 1.68 ± 0.05 m) with no lower limb injuries volunteered to participate. All subjects performed 5 successful trials of stair ascent and the same number trials of descent with a 3-stair staircase. Motion capture data (120 Hz, Vicon MX, Vicon, Centennial, CO, USA) and force data (1200 Hz, AMTI, Watertown, MA) were collected during each trial.

Raw force data and motion capture data were input into Matlab programs and low-pass filtered at 6 Hz. Inverse dynamics with rigid body assumptions was used to calculate 3-D joint moments and reaction forces at the hip, knee and ankle of the right leg. A musculoskeletal model was used to obtain maximal dynamic muscle forces, muscle moment arms and orientations for 43 lower limb muscles. Static optimization was used to select a set of muscle forces that minimized the sum of the squared muscle stresses and balanced the sagittal plane hip, knee and ankle moments and the frontal plane hip and ankle moments with the external moments for each frame of data. Muscle forces, joint reaction forces and joint moments were used to estimate the 3-D moments and forces at the midpoint of the femoral neck. These loads were then applied to a standardized elliptical model of the bone structure to estimate the stresses on the periphery of the inferior and superior portion of the ellipse model. The superior-inferior and anterior-posterior diameters of the model were 3.6 and 2.5 cm, which represented the diameters of the femoral neck; the superior-inferior and anterior-posterior thicknesses of the model were 0.6 and 0.3 cm, based on cortical bone thickness estimates of the femoral neck [5,6].

Differences in peak stresses and moments between stair ascent and descent were assessed by dependent t-test. All statistical tests were considered significant at p < .05. Statistical analyses were performed using IBM SPSS Statistics 19.

RESULTS

Table 1 shows the peak hip moments during stair ascent and descent. There was no statistical difference between peak abductor hip moments (p = 0.705), but the peak extensor hip moment was significantly greater during ascent compared to descent (p = .001).

Figure 1 and Table 1 show increased tension (positive values) at the superior site and increased compression (negative) at the inferior site of the femoral neck during stair descent. Stresses at both the superior and inferior sites displayed distinct peaks during the first half and second half of stance, so each peak was analyzed.
Significantly increased peak tensile stress was found in the 1\textsuperscript{st} peak at the superior site during the descent condition (p = 0.005), but the 2\textsuperscript{nd} peak showed no significant difference between stair ascent and descent (p = .098). Increased peak compressive stress at the inferior site during stair descent showed no significance in both peaks (P1: p = .105; P2: p = .071).

![Graph showing stresses at superior and inferior sites of the femoral neck.](image)

**DISCUSSION**

Peak tensile stress at the femoral neck increased in stair descent compared to ascent. On the other hand the peak hip extensor moment during stair navigation indicate greater loading during stair ascent. This agrees with a previous study comparing stair ascent and descent [4].

The 1\textsuperscript{st} peak tensile stress during stair descent could be explained by increased deceleration of the body due to a higher contact velocity. In addition, the relatively extended position of the hip during decent places more of the vertical load on the inferior neck. During ascent the flexed position of the hip during this period places the vertical loads more toward the posterior surface of the neck.

In this study, conclusions concerning the loading of the proximal femur were contradictory depending on if loading was assessed via hip joint moments or from femoral neck stresses. Increased femoral neck stresses could help explanation why some older adults have reported more hip pain in stair descent than ascent. Researchers may benefit from a more comprehensive evaluation of the loading environment by estimating bone stresses as well as joint moments during stair ascent and descent.

**REFERENCES**


**Table 1.** Means±SD of peak stresses at the superior and inferior sites of the femoral neck and peak hip moments during stair ascent and descent, P1 is the peak during the 1\textsuperscript{st} half of stance, P2 is for the 2\textsuperscript{nd} half.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Superior Tensile Stress</th>
<th>Inferior Compressive Stress</th>
<th>Abductor Hip Moment</th>
<th>Extensor Hip Moment</th>
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<tbody>
<tr>
<td></td>
<td>P1 (MPa)</td>
<td>P2 (MPa)</td>
<td>P1 (MPa)</td>
<td>P2 (MPa)</td>
</tr>
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<td>stair ascent</td>
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<td>10.8±3.9</td>
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<tr>
<td>stair descent</td>
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<td>14.4±5.4</td>
<td>33.1±6.2</td>
<td>32.5±9.9</td>
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