LATERAL SHEAR FORCES AT THE LOW BACK IN PERSONS WITH UNILATERAL TRANSFEMORAL AMPUTATION DURING OVERGROUND WALKING

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INTRODUCTION

The prevalence of low back pain (LBP) is considerably higher in persons with lower-extremity amputation (52-71%) compared to the general population (6-33%) [1]. Alterations in gait and movement among persons with lower-extremity amputation have been associated with overall increases in trunk and pelvic motion [2]. Persons with unilateral transfemoral amputation (TFA), specifically, tend to walk with larger lateral bending of the trunk toward the prosthetic side in single-limb stance [3]. Due to its relatively large mass compared to the whole body, increases in lateral trunk movement can substantially alter ground reaction force generation, thereby altering joint loads throughout the body [4]. As such, altered gait with increased trunk (and pelvic) motion among persons with TFA likely results in spinal loading patterns distinct from able-bodied individuals. Increased or asymmetric spinal loads are an important proximate cause of LBP [5]; repeated exposure to increased and altered spinal loads may therefore contribute, in part, to LBP onset and recurrence in this population. The goal of the present study was to quantify and compare lumbosacral (L5/S1) lateral shear forces in persons with and without unilateral TFA during overground walking.

METHODS

Data was collected retrospectively from twenty males with unilateral TFA and twenty male non-amputation controls that had completed previous gait evaluations (Table 1); these retrospective analyses were approved by the local IRB. All amputations were traumatic, and the mean (SD) time since amputation was 3.2 (1.7) years. Participants walked at their self-selected walking velocity across a 10m walkway. Kinematics were recorded (120Hz) using a full-body marker set and a 23-camera motion capture system (Vicon, Oxford, UK). Ground reaction forces were sampled (1200Hz) from four force platforms (AMTI, Watertown, MA, USA) embedded in the walkway. Since the calculation of joint forces at the low back requires responses from both lower extremities, multiple walking trials were collected to obtain 5 “clean” gait cycles; clean gait cycles were identified by clean right and left foot strikes on consecutive force platforms.

Table 1: Mean (SD) participant demographics.

<table>
<thead>
<tr>
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<th>Control</th>
<th>TFA</th>
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<tbody>
<tr>
<td>Age (yr)</td>
<td>28.1 (4.7)</td>
<td>29.5 (6.7)</td>
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<tr>
<td>Height (cm)</td>
<td>181.7 (6.4)</td>
<td>176.2 (6.7)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>85.0 (9.4)</td>
<td>80.6 (12.0)</td>
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</table>

Lumbosacral joint forces were calculated using a bottom-up inverse dynamics analysis, with a three-dimensional full-body link-segment model developed in Visual3D (C-Motion Inc., Germantown, MD, USA). The trunk was modeled as a single rigid segment, defined proximally by the acromia, C7, and sternal notch, and attached distally to the pelvis at the L5/S1 joint. The location of the L5/S1 joint was estimated using boney pelvis landmarks (ASIS and PSIS) and scaled by pelvis width [6]. L5/S1 lateral shear forces were normalized to participants’ body mass. Peak lateral trunk flexion angles in the global coordinate system (relative to vertical) were also calculated. Peak lumbosacral lateral shear forces and trunk lateral flexion angles were obtained during single-limb stance (per side), and averaged across the 5 clean trials for each participant.
Mixed-factor analyses of variance (ANOVA) were used to compare peak L5/S1 lateral shear forces and peak lateral trunk flexion angles between and within (bilaterally) groups. All statistical analyses were performed using JMP (Version 10, SAS Institute Inc., Cary, NC, USA), with statistical significance determined when \( p < 0.05 \). Summary values are reported as means (SD).

RESULTS AND DISCUSSION

Self-selected walking velocities were similar \( (p = 0.45) \) for participants with TFA and controls at 1.34 (0.06) and 1.36 (0.07) m/s, respectively. Overall, peak lumbosacral lateral shear forces were larger \( (p < 0.001) \) in participants with TFA compared to controls, with respective values of 1.03 (0.37) and 0.73 (0.20) N/kg. These were larger \( (p = 0.026) \) during prosthetic vs. intact single-limb stance among participants with TFA, but bilaterally similar \( (p = 0.094; \) i.e., minimal asymmetries) among controls (Fig. 1A). Of note, the lateral shear forces estimated here were directed towards the support leg during single-limb stance (i.e., right shear of trunk on pelvis during right-leg single support). Peak trunk lateral flexion was similarly larger \( (p < 0.001) \) overall in persons with TFA compared to controls [4.8 (2.8) vs. 2.0 (1.1) °]. Peak trunk lateral flexion was larger \( (p < 0.001) \) toward the prosthetic vs. intact limb in stance among participants with TFA, but bilaterally similar \( (p = 0.75) \) among controls (Fig. 1B).

Walking is generally less stable in the mediolateral than the anteroposterior direction, requiring active muscle control to maintain balance [8]. Specifically, balance of the trunk and pelvis about the supporting hip in single-limb stance requires a hip abduction moment to counteract the destabilizing laterally-directed gravitational forces and reduce pelvic drop [9]. Increased trunk lateral flexion toward the prosthetic side among persons with unilateral TFA has been suggested to help stabilize the body [10], perhaps as a compensation for weak (or missing) hip-stabilizing musculature in the residual limb. Such a strategy, however, appears to increase lumbosacral lateral shear forces during prosthetic single-limb stance. In conclusion, increased and asymmetric lateral shear forces at the low back combined with altered trunk (and pelvic) motion among persons with unilateral TFA may support a theory suggesting an association between repeated exposure to altered spinal loading and LBP onset and recurrence in this population.

REFERENCES


The views expressed in this abstract are those of the authors, and do not necessarily reflect the official policy of the Departments of the Army, Navy, Defense, nor the United States Government.