Gait & Posture 42 (2015) 204–209

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length Article

Persons with unilateral transfemoral amputation have altered lumbosacral kinetics during sitting and standing movements

Brad D. Hendershot [a,b,*], Erik J. Wolf [a,b,c]

[a] Department of Rehabilitation, Walter Reed National Military Medical Center, Bethesda, MD 20889, USA
[b] Department of Physical Medicine and Rehabilitation, Uniformed Services University of Health Sciences, Bethesda, MD 20814, USA
[c] DOD/VA Extremity Trauma and Amputation Center of Excellence, JBSA-Fort Sam Houston, TX, USA

ARTICLE INFO

Article history:
Received 26 November 2014
Received in revised form 30 March 2015
Accepted 18 May 2015

Keywords:
Biomechanics
Low back
Moment
Power
Trunk

ABSTRACT

Increases in spinal loading have been related to altered movements of the lower back during gait among persons with lower limb amputation, movements which are self-perceived by these individuals as contributing factors in the development of low back pain. However, the relationships between altered trunk kinematics and associated changes in lumbosacral kinetics during sit-to-stand and stand-to-sit movements in this population have not yet been assessed. Three-dimensional lumbosacral kinetics (joint moments and powers) were compared between 9 persons with unilateral transfemoral amputation (wearing both a powered and passive knee device), and 9 uninjured controls, performing five consecutive sit-to-stand and stand-to-sit movements. During sit-to-stand movements, lumbosacral joint moments and powers were significantly larger among persons with transfemoral amputation relative to uninjured controls. During stand-to-sit movements, lumbosacral joint moments and powers were also significantly larger among persons with transfemoral amputation relative to uninjured controls, with the exception of sagittal joint powers. Minimal differences in kinetic measures were noted between the powered and passive knee devices among persons with transfemoral amputation across all conditions. Altered lumbosacral kinetics during sitting and standing movements, important activities of daily living, may play a biomechanical role in the onset and/or recurrence of low back pain or injury among persons with lower-limb amputation.

1. Introduction

Altered gait mechanics with lower-limb amputation (LLA) are considered to contribute to the onset and recurrence of musculoskeletal injuries and/or pain [1]. With respect to low back pain (LBP) development, specifically, individuals with LLA perceive "uneven postures and compensatory movements of the back" as major contributing factors [2]. Numerous observational studies report larger and more asymmetric trunk-pelvic movements during gait in persons with versus without LLA (for a comprehensive review, see [3]). More recently, studies have focused on corresponding changes in lumbosacral kinetics during gait, comparing reactive joint loads at the low back in persons with and without LLA [4], as well as vertical spinal joint loading with foot-pylon adjustments in persons with unilateral transtibial amputation [5]. However, there remains a need to assess lumbosacral movement patterns and associated kinetics during other activities of daily living [3].

Sit-to-stand (and stand-to-sit) movements are common to everyday life and functionally important for maintaining mobility and independence [6]. Biomechanically, these movements are often considered more demanding than over-ground walking, as they require greater joint range-of-motion and muscle force to control the body's center-of-mass (COM) [7,8]. Sit-to-stand and stand-to-sit movements have therefore been used to evaluate functional limitations in various populations (e.g., [9,10]), and particularly those with unilateral neuromusculoskeletal impairments in the lower extremities [11,12]. These individuals consistently demonstrate weight bearing asymmetries among the lower extremities, with higher loads in the unaffected limb. Persons with unilateral LLA also tend to rely more upon their intact limb during gait [13], and lower-extremity kinetic asymmetries have been observed during sit-to-stand movements [14–16]. Yet, despite the upper body's substantial proportion of total body mass

* Corresponding author at: Department of Rehabilitation, Walter Reed National Military Medical Center, America Building (19), Room B-311, Bethesda, MD 20889, USA. Tel.: +1 301 400 3477.
E-mail address: bradford.hendershot@gmail.com (B.D. Hendershot).

http://dx.doi.org/10.1016/j.gaitpost.2015.05.011
0966-6362/

and importance to completion of the sit-to-stand and stand-to-sit task, there remain no studies examining lumbosacral kinetics during these movements among persons with unilateral LLA.

A recent investigation evaluated functional performance, using sit-to-stand and stand-to-sit movements, in persons with unilateral transfemoral amputation (TFA) wearing passive (C-Leg; Otto Bock Healthcare, Duderstadt, Germany) and powered (Power Knee™; Össur, Reykjavík, Iceland) microprocessor knee devices [17]. Although these authors noted larger mediolateral trunk displacements among persons with TFA compared to uninjured controls, regardless of knee device, no further (kinetic) trunk analyses were performed. Through re-analysis of that data, the purpose of the current study was to quantify and compare lumbosacral joint kinetics in persons with and without traumatic unilateral TFA during sit-to-stand and stand-to-sit movements. Also, given the available data, a secondary objective was to compare these responses between the C-Leg and Power Knee ("PK") devices. We hypothesized that lumbosacral kinetics would be larger among persons with TFA vs. uninjured controls during both sit-to-stand and stand-to-sit movements, particularly in the frontal or transverse planes as a result of compensatory trunk motion toward the intact limb. We further hypothesized that lumbosacral kinetics during sit-to-stand movements among persons with TFA would be more similar to able-bodied controls when using the PK vs. C-Leg prosthetic device, given the positive power generation at the knee mimicking concentric quadriceps function.

2. Methods

2.1. Participants

Following approval by the local Institutional Review Board, biomechanical data collected during sit-to-stand and stand-to sit movements were retrospectively analyzed from nine males with unilateral TFA – 5 initially fit with the PK and 4 with the C-Leg (cross-over design) – and nine male uninjured controls (for more information, see [17]). All participants were military personnel, with no self-reported neurologic or other musculoskeletal conditions or pain that may have adversely affected the results. Participants with TFA were all independent community ambulators (without the use of assistive devices), and at least 6 months post-amputation. Uninjured control participants were recruited to match persons with TFA. At the initial visit, mean (SD) age, stature, and body mass for the participants with TFA were 27.9 (5.4) years, 178.9 (5.5) cm, and 85.2 (10.9) kg, respectively. Corresponding values for the nine controls were 27.4 (3.6) years, 183.2 (7.7) cm, and 86.2 (6.2) kg (all p values >0.21). All amputations were a result of traumatic injuries, with a mean (SD) time since amputation of 1.4 (0.6) years at the time of testing.

2.2. Experimental procedures

Participants performed five consecutive sit-to-stand (and stand-to-sit) movements from (to) an arm- and back-less stool with a solid (i.e., not cushioned) seat surface; stool height was adjusted so that each participant's thighs were in a horizontal position and knees in 90° of flexion. Participants were instructed to rise (sit) at a comfortable pace without the use of their arms (hands placed on hips), and with each foot placed on two separate force platforms (AMTI, Watertown, MA, USA) in a consistent location across all five repetitions. There was a short (~3 s) pause in the standing position between sit-to-stand and stand-to-sit movements, with five seconds of rest between each repetition. Full-body kinematics were tracked (120 Hz) via retro-reflective markers using a 23-camera motion capture system (Vicon, Oxford, UK). Ground reaction forces were simultaneously recorded (1200 Hz) from the two force platforms. Raw marker and ground reaction force data were low-pass filtered using a bi-directional 4th order Butterworth filter, with a cutoff frequency of 6 Hz and 40 Hz, respectively.

2.3. Data analysis

Three-dimensional joint moments and powers at L5/S1 were computed using a 15-segment biomechanical model (cf. [4]) and bottom-up inverse dynamics approach in Visual3D (C-Motion Inc., Germantown, MD, USA). Since seat contact forces were not recorded, moments and powers at L5/S1 were analyzed in two time windows during each movement: (1) seat-off to static upright stance, and (2) static upright stance to seat-on. Seat-off (on) timing was determined when the vertical position of the pelvis center-of-gravity (COG) crossed a 10 mm threshold above the static COG position when seated on the stool (cf. [12]). To provide additional information during seat contact, trunk forward and lateral flexion angular velocities were also computed, as these can be used to infer differences in trunk angular momentum [18]. Trunk positions and angular velocities are calculated relative to the pelvis, using a sagittal–coronal–transverse rotation sequence. Net joint moments and powers at L5/S1 are normalized to total body mass.

2.4. Statistical analyses

Two sets of one-way repeated measures analyses of variance (ANOVA) were used to separately analyze all outcomes: one for sit-to-stand movements, and one for stand-to-sit movements. Although prosthetic knee type (i.e., Power Knee vs. C-Leg) is a within-subject factor, randomly assigned as part of the initial cross-over design from which this data was re-analyzed, we conservatively analyzed all data with knee as a between-subject factor with three levels (i.e., TFA with Power Knee, TFA with C-Leg, and uninjured controls). Note, two participants with TFA (initially fit with the C-Leg) were missing sit-to-stand and stand-to-sit data from the Power Knee condition. All statistical analyses were performed using SPSS (Version 21.0, IBM SPSS Inc, Chicago, IL, USA), with statistical significance determined when $p < 0.05$. For variables with significant group effects, post hoc comparisons were made using Tukey's honestly significant difference test. Summary statistics are presented as means (SD).

3. Results

3.1. Sit-to-stand

Total time to complete the sit-to-stand movements was similar ($p > 0.15$) between persons with TFA and controls, regardless of prosthetic knee type, at 1.88 (0.36) and 1.73 (0.27) s, respectively. Prior to seat-off, peak trunk flexion angular velocities were 40.5 (21.5), 48.9 (24.7), and 30.3 (15.5)°/s for control, TFA with PK, and TFA with C-Leg groups, respectively; corresponding peak trunk lateral flexion angular velocities during seat contact were 5.7 (3.8), 9.9 (10.2), and 14.3 (11.7)°/s. At the instant of seat-off, trunk forward/lateral flexion angles were 37.3 (7.9)/2.3 (1.8), 50.4 (16.3)/2.9 (1.9), and 45.8 (12.9)/3.3 (2.3)°, for control, TFA with PK, and TFA with C-Leg groups, respectively. Corresponding peak angles throughout the entire sit-to-stand movement generally increased, particularly the trunk lateral flexion angle among persons with TFA (Table 1), which were always directed toward the intact limb. Peak joint moments and powers were larger (all $p < 0.001$) among TFA with PK and C-Leg devices relative to controls (Table 1). The largest joint moments and powers occurred in the sagittal plane in both