KINETIC ANALYSIS OF THE SIT TO STAND TASK IN PERSONS WITH ERTL AND NON-ERTL TRANSTIBIAL AMPUTATIONS

[1]Abbie E. Ferris, [1]Jeremy D. Smith, [2]Cory L. Christiansen and [1]Gary D. Heise
[1]School of Sport & Exercise Science, University of Northern Colorado, Greeley, CO
[2]Interdisciplinary Movement Science Lab, University of Colorado, Anschutz Medical Campus, Denver, CO
email: abbie.ferris@unco.edu; website: http://www.unco.edu/biomechanics

INTRODUCTION

People with transtibial amputation (TTA) sit-to-stand (STAND) roughly 50 times per day [1], which suggests that this task is an important activity of daily living. While standing from a seated position, people with unilateral TTA produced 27% more peak vertical GRF with the intact limb compared with the amputated side [2].

During a below-knee amputation, traditionally the tibia and fibula are left free floating within the residual limb with no physical connection between the bones. During an osteomyoplastic amputation (commonly referred to as Ertl) a bone bridge is used between the tibia and fibula to stabilize the bones. It has been suggested that the bone-bridge improves functional outcomes after amputation [3] due to an enhanced "end-bearing" capability of the residual limb compared to the Non-Ertl technique [4].

The purpose of this study was to assess functional performance in Ertl and Non-Ertl TTA groups during a STAND task. It was hypothesized that those with an Ertl amputation would perform the task faster. We hypothesized that this better performance would result from a greater involvement of the amputated side in the Ertl group during the STAND task. Specifically, we anticipated that the Ertl group would load their amputated limb more than the non-Ertl group would load their amputated limb as evidenced by increased vertical GRF, joint powers, and joint work.

METHODS

Individuals with Ertl amputation (n = 11, 79.4 ± 16.7 kg, 1.77 ± 0.08 m) and Non-Ertl amputation (n = 7, 88.3 ± 16.0 kg, 1.78 ± 0.08 m,) were recruited. Inclusion criteria included: amputation resulting from trauma, no concomitant musculoskeletal injuries, neurological, or visual impairments, and physically active 3 days a week.

A chair, with its legs adjusted to the fibular height of the participant, was placed adjacent to two force plates embedded in the floor. Participants were instructed to sit comfortably on the chair with each foot positioned on separate force plates. Participants were then asked to stand up and wait for a verbal cue to begin a five-time, sit-to-stand clinical task as quickly as possible without pushing with upper limbs. During the task participants were required to make complete contact with their bottom on the chair before standing to complete the repetition. A full body marker set was applied to various anatomical landmarks prior to data collection. Motion (100 Hz) and GRF (2000 Hz) data were collected during each trial. In addition, a stop watch was used to measure the time it took each participant to complete the task.

The middle three repetitions of the STAND motion were analyzed. Peak vertical GRFs, normalized to body weight, for each limb were identified for each repetition. The peak force was used to calculate a symmetry index (SI) between the two limbs (intact (*I*) and amputated (*A*)) [5]:

$$SI = 100 - 100 * \frac{I - A}{(I + A)}$$

A t-test was used to test for significant differences in sit-to-stand time between the groups ($\alpha = .05$, SAS 9.4, Cary, NC). A single factor MANOVA (α=.05) with predetermined orthogonal contrasts was used to evaluate between-group and between-limb differences in joint power and work.

RESULTS AND DISCUSSION

The Ertl group performed the sit-to-stand task significantly faster (p = .005) than the Non-Ertl group (9.33 ± 2.66 s vs 13.27 ± 2.83 s). Peak GRFs, were significantly smaller for the amputated limb compared to the intact limb for both groups (Table

1). The Ertl amputated limb produced significantly (p = .033) more peak vertical force than the Non-Ertl amputated limb (Table 1). The SI between limbs was less than 100 for both groups (88.35 ± 11.90 Ertl, 85.15 ± 7.31 Non-Ertl) indicating that the intact limb produced more force than the amputated limb. However, GRF asymmetry was similar between Ertl and Non-Ertl groups.

Table 1. Peak ground reaction forces, as a percentage of body weight (BW), for the amputated and intact limbs (mean ± SD).

Group	Amputated GRF (%BW)	Intact GRF (%BW)
Ertl	63.3 ± 8.4	80.3 ± 11.6*‡
Non-Ertl	52.5 ± 8.0*	71.1 ± 11.0‡

Note. *Significantly different from Ertl amputated limb (p < .05)
‡Significantly different from Non-Ertl amputated limb (p < .05)

Peak knee power of the amputated limb for both groups was significantly smaller (~65% smaller) than their respective intact limb (Table 2). However, the Ertl intact limb produced significantly greater peak knee power (~50% greater) than the Non-Ertl intact knee. No significant differences were found between limbs or groups at the hip. However, the Ertl amputated limb showed a trend toward producing more peak hip power than the Non-Ertl amputated limb (p = .078).

Table 2. Peak Power ($W \cdot kg^{-1}$) for the knee and hip (mean ± SD).

Group	Amputated		Intact	
	Knee	Hip	Knee	Hip
Ertl	1.02 ± 0.53	2.06 ± 0.85	2.92 ± 1.25*‡	1.95 ± 1.15
Non-Ertl	0.71 ± 0.34	1.25 ± 0.73	1.99 ± 0.67 *‡†	1.86 ± 0.72

Note. *Significantly different from Ertl amputated limb (p < .05)
‡Significantly different from Non-Ertl amputated limb (p < .05)
†Significantly different from Ertl intact limb(p < .05)

At the knee, the amputated limb for both groups generated significantly (all *p-values* < .033) less total work than the intact limbs (Table 3). The Ertl intact limb also produced more work at the knee than at the knee of Non-Ertl intact limb (p = .010).Thus, the faster time of the Ertl group appears to be driven by greater power and work production at the knee of the intact limb and possibly the hip of the Ertl amputated limb.

Clinically, the most relevant result of this study was that Ertl TTA performed the STAND task ~30% faster than the Non-Ertl group. This suggests that there is a functional advantage of the Ertl over Non-Ertl TTAs; this finding differs from the literature, which reports there are no self-reported functional differences between groups [6, 7].

Table 3. Total work (J) for the knee and hip joints (mean ± SD).

Group	Amputated		Intact	
	Knee	Hip	Knee	Hip
Ertl	0.20 ± 0.14	0.65 ± 0.28	0.76 ± 0.25*‡	0.51 ± 0.33
Non-Ertl	0.26 ± 0.24	0.42 ± 0.21	0.51 ± 0.21 *‡†	0.62 ± 0.24

Note. *Significantly different from Ertl amputated limb (p < .05)
‡Significantly different from Non-Ertl amputated limb (p < .05)
†Significantly different from Ertl intact limb (p < .05)

In relative terms, the contribution of the amputated limb to the overall movement was similar between groups and was similar to previous reports [2, 5]. In absolute terms, expressed as a percentage of BW, the Ertl amputated limb produced more vertical GRF than the Non-Ertl amputated limb. However, the Ertl group performed the STAND task faster not just because of increased GRF on the amputated side, but also with increased GRF on the intact side.

Furthermore, the Ertl intact limb produced significantly larger peak knee joint powers and total knee work than the Non-Ertl intact limb. The increased demands on the intact Ertl knee could be seen as a harmful compensation strategy over time. However, an alternative explanation may suggest that decreases in knee extensor strength may decrease the ability to perform the sit-to-stand task without additional assistance from the hip and ankle during the STAND task [8]. This may suggest that the Ertl intact leg knee extensors were stronger than the Ertl amputated limb and the Non-Ertl group. There is need for a prospective study to better understand the impacts of increased load production with Ertl TTA and whether this has an influence on osteoarthritis development over time.

To our knowledge, this is the first study to evaluate the functional performance differences between the Ertl and Non-Ertl amputation techniques. These results suggest that functional differences do exist between the Ertl and Non-Ertl procedures.

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