WEIGHT BEARING ASYMMETRIES AND CHANGES IN COP TRAJECTORIES: UNILATERAL ERTL AMPUTEES VS NON-AMPUTEES

[1]Abigail L. Carpenter, [1]Jeremy D. Smith, [2]Cory L. Christiansen, and [1]Gary D. Heise
[1]Biomechanics Laboratory, University of Northern Colorado, Greeley, CO
[2]Interdisciplinary Movement Science Lab, University of Colorado, Anschutz Medical Campus, Denver, CO
email: abigail.carpenter@unco.edu, web: www.unco.edu/nhs/ses

INTRODUCTION

Lower extremity amputation often results in a weight bearing asymmetry between prosthetic and intact sides for unilateral amputees. This asymmetry is thought to contribute to greater fluctuations in center of pressure (COP) trajectories during quiet standing for unilateral amputees [1]. Specifically, medial-lateral (ML) and anterior-posterior (AP) COP excursions and velocities are greater for the prosthetic side compared to the intact leg or leg of a non-amputee [1-3].

Transtibial osteomyoplastic amputation, commonly referred to as the "Ertl technique", is designed to improve the healing process of the residual limb by improved surgical remodeling of the amputation site [4]. The Ertl technique involves sealing off the medullary cavity of the amputated bones via a bone bridge and/or by salvaging some of the periosteum during the amputation and using the periosteum to cover the exposed end of the medullary cavity. Although effects of the Ertl technique on wound healing and tissue recovery have been described in the research literature [e.g., 4], little is known about functional outcomes following an Ertl amputation.

The purpose of the study was to determine how bilateral postural control in unilateral, transtibial amputees who received an Ertl-type amputation compares with an age-matched non-amputee control group. Our expectation was that as demands on the postural control system increased the intact leg would be more relied on to control posture as evidenced by an increased weight bearing on the intact leg, whereas asymmetry in the control group would be unaltered across conditions.

METHODS

Five unilateral, transtibial amputees who received an Ertl amputation (age = 38 ± 7 yrs, height = 1.8 ± 0.1 m, mass = 79.8 ± 13.8 kg) and five age-matched controls (age = 38 ± 8 yrs, height = 1.8 ± 0.1 m, mass = 81.3 ± 17.1 kg; right limb dominant) participated in this study. Ground reaction force (GRF) data (1000 Hz) from two plates (one under each foot) were collected while participants stood on 1) a rigid surface with eyes open (RSEO), 2) a rigid surface with eyes closed (RSEC), 3) a compliant surface with eyes open (CSEO), and 4) a compliant surface with eyes closed (CSEC). Vertical GRFs (VGRF) and COP data were resampled at 100 Hz prior to analysis. Only the middle 20 s of each 30 s trial were analyzed. For VGRFs, the mean for each leg was determined over the entire 20 sec trial to assess weight bearing asymmetry. For COP data, four commonly used measures from the literature were identified; mean AP and ML COP velocities and mean AP and ML frequencies. A series of three-factor ANOVA's (Limb, Surface, and Vision) were used to determine the effects of each condition on COP and VGRF measures. Significant main effects were reported at $p \leq .05$ and interaction effects at $p \leq .10$.

RESULTS AND DISCUSSION

Weight bearing asymmetries in Ertl amputees were approximately 4% when standing on a rigid surface with their eyes open or closed (Figure 1). This weight bearing asymmetry was similar to the control group for the rigid surface. In addition, a 6% weight bearing asymmetry has been reported for skilled prosthetic users with a unilateral, transtibial amputation [1]. However, for both controls and amputees significant leg by surface ($p < .03$, $p < .05$, respectively) and leg by vision ($p < .09$, $p < .10$, respectively) interactions were observed. This suggested as demand on the postural system increased, amputees distributed more weight to the prosthetic side and controls distributed more weight to the left side. As Figure 1 illustrates, weight bearing asymmetry was exacerbated more in amputees than controls as demand increased, particularly on the compliant surface.

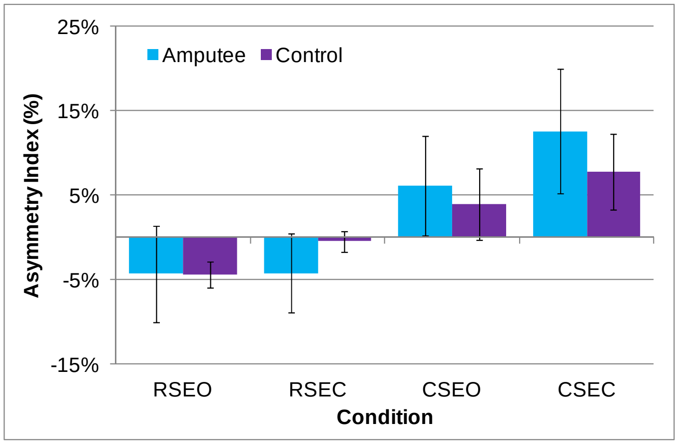

Figure 1: Weight bearing asymmetries across quiet standing conditions. Asymmetry was determined by dividing the difference between limbs by the average value for both legs. Positive percentages indicate the prosthetic side value was larger, and for controls the left leg value was larger.

For COP based measures in amputees, interaction effects between limb and surface (*p* < .07) and limb and vision (*p* < .01) occurred for mean AP COP velocity. However, mean ML COP velocity in amputees only exhibited an interaction between limb and visual input (*p* < .06). In general, as postural demands increased mean COP velocity for the prosthetic side increased to a greater extent than the intact side (Figure 2). Interestingly, our results are contrary to results from the literature where COP velocities are generally greater for the intact leg, rather than the prosthetic side. In the control group, no limb interaction effects were observed with AP or ML velocity measures, but main effects for surface (*p* < .01, *p* < .01, respectively) and vision (*p* < .02, *p* < .02, respectively) were detected. Thus, in the control group COP velocity was not dependent on the leg, but did increase with the eyes closed on the compliant surface.

For mean AP COP frequency, amputees revealed interaction effects for both limb by surface (*p* < .02) and limb by vision (*p* < .03), suggesting changes in AP frequency depend not only on prosthetic or intact leg, but also upon the surface or vision condition. Controls, however, only showed changes based on visual input (*p* < .05) with no dependence on leg. ML frequency in amputees was dependent on limb (*p* < .01), with a greater frequency for the intact limb. In controls, limb was only significant based on changes in surface (*p* < .05).

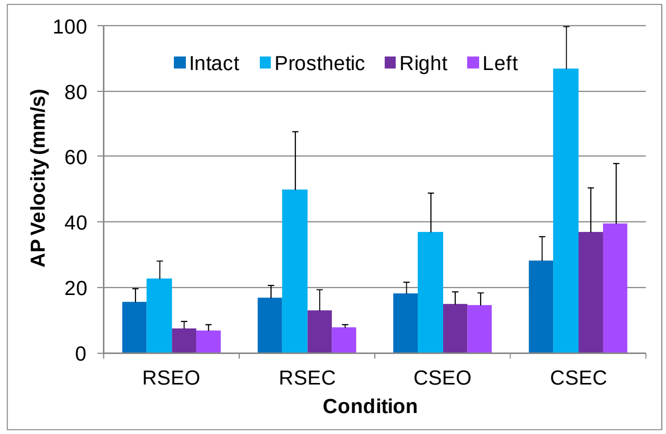

Figure 2: COP AP mean velocity across conditions.

CONCLUSIONS

Ertl amputees relied more on the prosthetic leg to control posture as demands increased, whereas control subjects relied more on the left limb. Surprisingly, it appears that Ertl amputees relied on the prosthetic side for stability, whereas controls relied on the non-dominant leg for stability. Further research is needed with comparisons between Ertl amputees and traditional amputees to determine whether this observation is unique to Ertl amputees.

REFERENCES

1. Mayer et al. (2011). *BMC Musculoskeletal Disorders*, 12, 118-124.
2. Buckley et al. (2002). *Am J Phys Med Rehabil*, 81, 13-20.
3. Hlavackova et al. (2011). *Plos One*, 6, e19661.
4. Dionne et al. (2009). *J Prosth Orthot*, 21, 64-70.

ACKNOWLEDGEMENTS

We would like to acknowledge Dr. David Hahn for assistance with recruitment and his medical expertise with this project.