THE EFFECTS OF WALKING SPEED AND SURFACE ON DYNAMIC STABILITY IN YOUNG ADULTS WITH UNILATERAL TRANS-TIBIAL AMPUTATIONS

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INTRODUCTION

Dynamic stability is commonly defined as the ability to maintain balance during locomotion. Hof (2005) introduced a dynamic stability margin (DSM) based on how the center of mass (COM) moves relative to the base of support. Unilateral trans-femoral amputees exhibited larger DSMs on their involved sides. These also increased at faster walking speeds (Hof 2007). This finding seems counterintuitive and suggests that amputees adopt larger DSMs to *compensate* for an increased sensitivity to perturbations (either real or perceived). DSMs have not been assessed when walking stability has been overtly challenged.

Patients with locomotor impairments are especially challenged when walking over uneven or unstable surfaces (Richardson 2004). To date, however, these studies have not yet controlled for walking speed. This study determined how both walking speed and an uneven surface affected DSMs in adults with unilateral trans-tibial amputation (TTA). We hypothesized that DSMs would increase on the involved side at faster walking speeds and would also increase more on the involved limb when walking over loose gravel.

METHODS AND PROCEDURES

Five male military service members (27.6 ± 5.4 yrs) volunteered to participate with written informed consent (Table 1). All patients had unilateral TTA. These were due to blast related injuries in 3 patients, gunshot wounds in 1 patient, and a motorcycle accident in 1 patient. Prosthetic devices varied for subjects based on individual needs.

Patients walked at 3 height-adjusted speeds over both a level walkway and a loose gravel surface. All subjects completed 6-10 trials over each surface at each speed. Full body kinematics were recorded during each trial using 55 markers and a 19 camera Motion Analysis system. A 15-segment model was used to estimate whole body COM motions.

Frontal plane DSMs were defined as the minimum perpendicular distance between the velocity adjusted COM vertical projection and the lateral borders (5^{th} metatarsal head) of the forward supporting foot (Hof 2005). In theory, larger DSMs should reflect a safer (i.e., more stable) gait pattern (Hof 2005). Minimum DSM values during the stride were extracted for statistical analyses. A three factor ANOVA was used to determine differences between limbs, speeds, and surfaces.

RESULTS

DSMs exhibited minima shortly after heel strike (Fig. 1), as in Hof (2005, 2007). Minimum DSMs (Fig. 2) were significantly larger when patients walked on the gravel surface compared to level ground ($p = 0.037$). There was a trend for DSMs to increase slightly at faster walking speeds ($p = 0.097$). There were no significant differences between involved and uninvolved limbs ($p = 0.321$). There were no significant interaction effects.

There were occasional individual subject trials over the loose gravel where the DSMs were only a few millimeters. During these trials, some subjects exhibited stumbling responses, including occasional cross-over stepping. However, the DSMs never became negative and no subject experienced a fall.

Subject - Limb*	Age (yr)	Ht (m)	Wt (kg)	Time in Prosthesis (wk)
1 - L	26	1.80	67.50	8
2 - R	19	1.72	63.18	17
3 - L	32	1.86	83.86	120
4 - L	29	1.75	75.50	8
5 - R	32	1.76	77.27	21

Table 1. Demographic data for patients with trans-tibial amputation. *The prosthesis limb.

DISCUSSION

Patients adapted to the unstable loose gravel surface by increasing their DSMs. This provides additional evidence that these DSMs reflect how patients *compensate* to maintain balance when their stability is challenged. This directly extends recent results presented in trans-femoral amputees (Hof 2007). However, it is not yet known if these changes in DSM directly predict changes in fall risk.

The lack of differences between intact and prosthetic limbs in these TTA patients contrasts with previous results obtained in trans-femoral patients (Hof 2007). This was likely due either to differences in level of amputation, activity/fitness level, or both. That the TTA patients in this study achieved relatively symmetric gait patterns and DSMs supports the idea that amputees do not have to sacrifice symmetry to achieve sufficient stability.

Further research needs to determine how these DSMs are related to actual fall risk and how gait symmetry, stability, and fall risk are inter-related in both trans-tibial and trans-femoral amputees. The present findings nevertheless provide important insights into how TTA patients adapt their gait patterns to challenging walking environments.

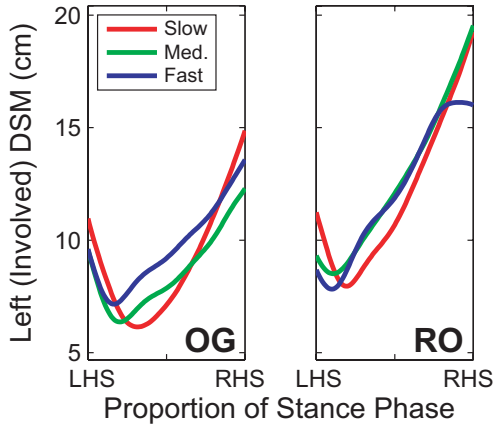

Figure 1. DSMs for the involved limb of a typical subject while walking over level ground (OG) and loose gravel (RO).

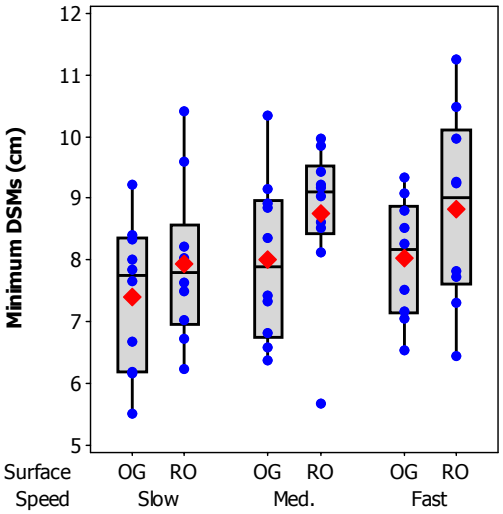

Figure 2. Box plots of DSMs. Dots are individual means, diamonds are group means. OG=overground (level), RO=rocks (gravel).

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