THE GAIT INITIATION PROCESS IN UNILATERAL LOWER-LIMB AMPUTEES STEPPING TO A NEW LEVEL

[1]Steven F. Jones, [1]Peter C. Twigg, [2]Andrew J. Scally and [3]John G. Buckley
[1]School of Engineering, Design and Technology, [2]School of Health Studies and [3]School of Life Sciences,
University of Bradford, Richmond Road, Bradford, West Yorkshire, UK; email: s.f.jones1@bradford.ac.uk

INTRODUCTION

Because feedback originating from cutaneous receptors within the foot and leg is only present unilaterally [1], or at best is available via re-mapped receptors within the stump [2], unilateral lower-limb amputees will need to adopt alternative balance and postural control strategies when initiating gait. Also, because amputees are taught to lead with their intact limb when stepping up and with their prosthetic limb when stepping down, they may employ a different gait initiation strategy for each stepping direction. The aim of the present study was to determine the balance and postural control adaptations used by unilateral lower-limb amputees when stepping up and when stepping down to a new level.

METHODS

Ten unilateral amputees (5 transfemoral and 5 transtibial) and 8 able-bodied controls performed single steps up and single steps down to a new level (73 and 219 mm). Amputee subjects stepped up leading with their intact limb and stepped down leading with their prosthesis.

Phase duration, a-p and m-l centre of mass (CoM) and centre of pressure (CoP) peak displacements and CoM peak velocity of the anticipatory postural adjustment (APA) and step execution (SE) phase were evaluated for each stepping direction by analysing data collected using a Vicon 3D motion analysis system. Data were analysed using a random effects population averaged model. Also, to highlight differences in CoM/CoP interactions between each group, data were compared qualitatively (exemplar, Figure 1).

RESULTS AND DISCUSSION

There were significant differences (in the phase duration, peak a-p and m-l CoP displacement, and peak a-p and m-l CoM velocity at heel-off and at foot-contact) between both amputee sub-groups and controls ($P < 0.05$), but not between amputee sub-groups. These group differences were mainly a result of amputees adopting a different gait initiation strategy for each stepping direction (Table 1). In transfemorals this may have been a way, when stepping up, of ensuring the GRF vector was anterior of the knee joint centre; this would have helped to keep the knee of the prosthetic limb fully extended (locked). In transtibials it may have been a way to reduce the knee extensor moment, thereby reducing the force of the prosthesis against the distal end of the tibia. When stepping down (landing on the prosthesis) both amputee sub-groups adopted a ‘cautionary’ approach.

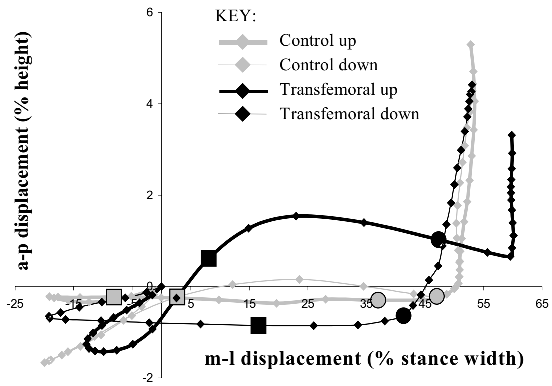

Figure 1. ‘Ensembled average’ CoP trajectories for transfemoral amputees vs. controls when stepping up to and down from the low step height. Distance between points represents movement speed. Data are shown from movement initiation up to swing limb foot-contact. ☐ and ○ indicates the instant of heel- and toe-off of the swing limb respectively.

CONCLUSIONS

Findings indicate the gait initiation process utilised by lower-limb amputees was dependent on the direction of stepping and, more particularly, by which limb the amputee led with. This suggests that the balance and postural control of gait initiation is not governed by a fixed motor program, and thus that an amputee will require time and training to develop alternative neuromuscular control and coordination strategies. These findings should be considered when developing training and/or rehabilitation programs.

REFERENCES

1. Geurts ACH, et al. Postural reorganisation following lower limb amputation. *Scand J Rehabil Med* **24**, 83-90, 1992.
2. Schwenkreis P, et al. Reorganization in the ipsilateral motor cortex of patients with lower limb amputation. *Neurosci Lett* **349**, 187-190, 2003.

ACKNOWLEDGEMENTS

Steve Jones is supported by a studentship from the Engineering and Physical Sciences Research Council, UK.
Steve Jones gained a matching ‘Doctoral Dissertation Grant’ award from the International Society of Biomechanics.
Chas. A. Blatchford & Sons Ltd, Basingstoke, UK, provided prosthetic and clinical support.

Table 1: Mean (SD) temporal and kinematic parameters averaged across step height when stepping up and stepping down.

		Controls		Transfemorals		Transtibials	
		Up	**Down**	**Up**	**Down**	**Up**	**Down**
APA phase	APA duration (% movement)	30.7 (7.8)	39.1 (7.1)**	47.5 (4.3)**	37.0 (5.4)	42.2 (7.5)**	31.9 (8.2)
	Peak a-p CoP (% height)	-0.81 (-0.5)	-1.8 (-0.7)**	-1.5 (-0.8)**	-1.0 (-0.5)	-1.1 (-0.5)**	-0.8 (-0.4)
	Peak m-l CoP (% stance)	22.81 (7.9)	20.8 (8.5)	13.9 (4.4)**	20.1 (6.7)	16.3 (4.3)	17.9 (4.8)
	m-l CoM vel. HO ($mm.s^{-1}$)	190.1 (56.8)**	178.1 (44.2)	159.9 (32.7)**	150.1 (44.6)	212.8 (34.3)**	175.2 (38.4)
	a-p CoM vel. HO ($mm.s^{-1}$)	91.1 (31.7)	129.6 (37.4)**	112.0 (49.8)*	64.7 (14.3)	86.3 (37.7)*	54.5 (18.9)
SE phase	Peak m-l CoM (% stance)	26.9 (3.4)*	23.6 (4.8)	23.2 (4.8)	24.0 (7.6)	31.0 (5.9)*	27.0 (4.5)
	m-l CoM vel. FC ($mm.s^{-1}$)	334.9 (73.9)**	301.4 (74.0)	303.9 (47.8)**	240.0 (46.2)	360.2 (45.5)**	318.8 (54.6)
	a-p CoM vel. FC ($mm.s^{-1}$)	511.0 (29.1)	622.1 (106.0)**	462.4 (75.7)	457.3 (90.8)	485.7 (64.4)	511.9 (69.7)
	Movement time (s)	1.29 (0.14)*	1.19 (0.16)	1.18 (0.23)	1.31 (0.21)*	1.38 (0.23)	1.47 (0.20)*

Differences between stepping direction are indicated as $^{**}P < 0.001$, $^{*}P < 0.05$. NB, m-l CoP displacements during the APA phase were directed towards the intended swing limb, whereas during the SE phase they were directed towards the stance limb. HO = heel-off, FC = foot-contact.