NOVEL ASSESSMENT OF GAIT AND MOBILITY FUNCTION IN TRANSTIBIAL AMPUTEES

Submitted by Brenton Graham Hordacre

BPhty (Hon), University of South Australia, Adelaide

For the Degree of Doctor of Philosophy in the

Department of Rehabilitation, Aged and Extended Care

School of Health Sciences, Faculty of Medicine, Nursing and Health Sciences

Flinders University, Adelaide, Australia

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SUMMARY

Lower-limb amputees require extensive rehabilitation to restore gait and mobility function and achieve successful re-integration into the community. Decreasing length of hospital stays and resources shortages have increased the need for more efficient treatment to hasten recovery. However, complex issues such as older age, various levels of amputation and associated comorbidities pose additional challenges to the restoration of gait and mobility function. Much research into lower-limb amputees has focussed on vascular interventions and prosthetic technology, with limited literature investigating alternative approaches to characterise gait and mobility function. A good understanding of issues influencing amputee rehabilitation is necessary to help identify aspects of amputee rehabilitation requiring attention and to drive more effective and efficient rehabilitation approaches. New assessments of gait and mobility function have the potential to progress our understanding of lower-limb amputee rehabilitation. The purpose of this thesis was to investigate novel assessments of gait and mobility function in transtibial amputees. These assessments were investigated from a clinical rehabilitation perspective to determine their potential contribution to future amputee rehabilitation.

There are four sections to this thesis. The first section established the state of amputee rehabilitation in Australia by reviewing contemporary data from amputee rehabilitation services at a national level (n = 6,588), and from a single regional rehabilitation service (n = 531). Trends for increasing length of stay and decreasing age were identified. Many amputees (43.4%) presented with multiple comorbidities. Time to achieve key rehabilitation milestones increased over the period of

observation. These findings identified shifts in patient characteristics which affected the timely and optimal restoration of function by amputee rehabilitation services. New and novel assessments of gait and mobility function may assist future amputee rehabilitation and should be investigated. Greater understanding of amputee gait and mobility may allow for more efficient functional assessments and identify individuals likely to need additional therapy input, assisting rehabilitation units in planning and prioritising treatment.

The second section of the thesis investigated the potential that spatial-temporal gait variability has as a measure of gait function in transtibial amputees. Forty-seven community dwelling amputees were recruited from the single prosthetic rehabilitation facility reviewed in the first section of this thesis. The influence of intra-subject gait speed variability was examined and the variability of speed normalised spatial-temporal gait parameters was calculated for individual participants. Greater normalised gait variability was observed in amputees with a history of falls. This study identified that gait variability may be an important measure of gait function and additionally demonstrated the importance of normalising for walking speed in the analysis of gait variability.

The third section of the thesis investigated wearable technology as a novel method to assess community activity and participation. Amputees recruited for the previous gait variability study also participated in this experiment. Data from an accelerometer based device to assess step counts, and a global positioning system (GPS) to assess community visits, were linked to identify community activity and participation. Measures of activity and participation in the community were negatively associated with normalised gait variability, further suggesting gait variability is an important clinical marker of gait function.

The final section of the thesis investigated the use of transcranial magnetic stimulation to determine if neurophysiological measures of brain function may assist clinical practice as neural biomarkers of gait function. A subset of community living transtibial amputees who had participated in the previous studies were recruited. A ratio of corticomotor excitability of ipsilateral and contralateral projections to the amputated limb (index of corticospinal excitability, ICE) was calculated. Relatively greater excitability of ipsilateral compared to contralateral projections to motoneurons innervating residual muscles of the amputated limb was associated with increased normalised gait variability. Further investigation of the contribution of ipsilateral and contralateral motor cortex to gait function was conducted in amputees completing prosthetic rehabilitation. Bilateral reorganisation of the motor cortex occurred following lower-limb amputation and continued through prosthetic rehabilitation. Intracortical inhibition within a hemisphere at key phases of rehabilitation was predictive of gait function at discharge. For the contralateral motor cortex, reduced intracortical inhibition at admission to rehabilitation and when undertaking first walk with a prosthetic limb was associated better gait function. However, for the ipsilateral motor cortex, reduced intracortical inhibition at discharge from rehabilitation was associated with poor gait function. Combining outcomes from these two studies, it appears that ongoing cortical reorganisation of the ipsilateral motor cortex following rehabilitation is associated with poor gait function. Both ICE and intracortical inhibition may be appropriate neurophysiological biomarkers of gait function in transtibial amputees.

In summary, three aspects of gait and mobility function in transtibial amputees were investigated. These findings expand current understanding of amputee gait and mobility and demonstrate the importance of investigating alternative assessments that may improve outcomes of clinical rehabilitation. The results of the work in this thesis have potential to improve understanding and knowledge of transtibial amputee rehabilitation and may inform future studies to improve outcomes of amputee rehabilitation.

PUBLICATIONS ARISING FROM THIS RESEARCH

Refereed manuscripts

Hordacre, B, Bradnam, L, Barr, C, Patritti, BL & Crotty, M 2014, ‘Ipsilateral corticomotor excitability is associated with increased gait variability in unilateral transtibial amputees’, *European Journal of Neuroscience*, vol. 40, no. 2, pp. 2454-62.

Hordacre, B, Barr, C & Crotty, M 2014, ‘Use of an activity monitor and GPS device to assess community activity and participation in transtibial amputees’, *Sensors*, vol. 14, no. 4, pp. 5845-59.

Hordacre, B & Bradnam, L 2013, 'Reorganisation of primary motor cortex in a transtibial amputee during rehabilitation: A case report', *Clinical Neurophysiology*, vol. 124, no. 9, pp. 1919-21.

Hordacre, B, Birks, V, Quinn, S, Barr, C, Patritti, BL & Crotty, M 2013, 'Physiotherapy rehabilitation for individuals with lower limb amputation: a 15-year clinical series', *Physiotherapy Research International*, vol. 18, no. 2, pp. 70-80.

Hordacre, BG, Stevermuer, T, Simmonds, F, Crotty, M & Eagar, K 2013, 'Lower-limb amputee rehabilitation in Australia: Analysis of a national data set 2004-10', *Australian Health Review*, vol. 37, no. 1, pp. 41-7.

Invited conference concurrent session presentations

Hordacre, B, Bradnam, L, Barr, C, Patritti, BL & Crotty, M 2013, 'Emerging Technologies In Amputee Rehabilitation: “What will the Future Look Like?”', paper presented to 2nd Singapore Rehabilitation Conference, Singapore.

Conference abstracts

Hordacre, B, Bradnam, L, Barr, C, Patritti, BL & Crotty, M 2014, 'Influence of the ipsilateral motor cortex on functional performance in unilateral transtibial amputees', paper presented to Australasian Military Medicine Association, Adelaide, Australia.

Hordacre, B, Bradnam, L, Barr, C, Patritti, BL & Crotty, M 2014, 'Reorganisation of the primary motor cortex in amputees undertaking prosthetic rehabilitation', paper presented to Australasian Neuroscience Society: Sensorimotor Satellite Meeting, Adelaide, Australia.

Hordacre, B, Bradnam, L, Barr, C, Patritti, BL & Crotty, M 2013, 'The relationship of ipsilateral and contralateral projections to the quadriceps on control of gait and balance in transtibial amputees', paper presented to Australasian Brain Stimulation Meeting, Melbourne, Australia.

Hordacre, B, Bradnam, L & Crotty, M 2013, 'Reorganisation of the primary motor cortex in amputees undertaking prosthetic rehabilitation', paper presented to Australasian Brain Stimulation Meeting, Melbourne, Australia.

Hordacre, B, Bradnam, L, Barr, C, Patritti, BL & Crotty, M 2012, 'Influence of the ipsilateral motor cortex on functional performance in unilateral transtibial amputees', paper presented to New Zealand Applied Neuroscience Conference, Auckland, New Zealand.

Hordacre, B, Birks, V, Quinn, S, Barr, C, Patritti, B & Crotty, M 2011, 'Changes in rehabilitation outcomes of lower limb amputees over 15 years: A clinical series', paper presented to Annual Scientific Meeting of ISPO Australia, Sydney, Australia.

Accepted conference abstracts

Hordacre, B, Barr, C & Crotty, M 2014, ‘Wearable technology to assess community activity and participation in transtibial amputees’, paper presented to 22nd Annual Scientific Meeting of the Australasian Faculty of Rehabilitation Medicine, Adelaide, Australia.

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge I believe it does not contain any material previously published or written by another person except where due reference is made in the text.

The study in chapter three was conceived by myself and MC. I was responsible for applying for ethical approval. Data were obtained from the Australasian Rehabilitation Outcomes Centre (Wollongong, NSW). Data analyses were performed by myself under the guidance of TS. Interpretation of the data was completed by myself and MC. I was responsible for drafting the manuscript, and TS, FS, MC, KE reviewed the manuscript. The study in chapter four was conceived by myself, CB, BP and MC. I was responsible for applying for ethical approval. Data were collected by VB. I conducted data analyses under guidance from SQ. Interpretation of the data were completed by myself, CB, BP and MC. I was responsible for drafting the manuscript, and VB, SQ, CB, BP, MC reviewed the manuscript. The study in chapter five was conceived by myself and CB. I was responsible for applying for ethical approval, participant screening and recruitment, data collection, analysis and interpretation. I was responsible for drafting the manuscript, and CB, BP and MC reviewed the manuscript. The study in chapter six was conceived by myself and CB. I was responsible for applying for ethical approval, participant screening and recruitment, data collection and analysis. Interpretation of data was completed by myself and CB. I was responsible for drafting the manuscript, and CB, BP and MC reviewed the manuscript. The study in chapter seven was conceived by myself and

LB. I was responsible for applying for ethical approval, participant screening and recruitment, data collection and analysis. Interpretation of data was completed by myself and LB. I was responsible for drafting the manuscript, and LB, CB, BP and MC reviewed the manuscript. The study in chapter eight was conceived by myself and LB. I was responsible for applying for ethical approval, participant screening and recruitment, data collection and analysis. Interpretation of data was completed by myself and LB. I was responsible for drafting the manuscript, and LB and MC reviewed the manuscript.

I took a leadership role in preparing all manuscripts for submission to journals, and responding to reviewer comments. These responses were reviewed by all co-authors before re-submitting to the journals.

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