Institution: University of Roehampton

Unit of Assessment: Panel A, UoA 3 Allied Health Professions, Dentistry, Nursing and Pharmacy

Title of case study: Enhancing Mobility for Lower Limb Amputees

1. Summary of the impact

This case study examines the long-term and ongoing relationship between an industrial collaborator (Chas A Blatchford & Sons Ltd) and researchers at the University of Roehampton. This systematic programme of biomechanical research on how prostheses perform in activities other than walking has had two significant outcomes. Firstly, this work has significantly improved prosthetic design, with four new prosthetic designs marketed worldwide. Secondly, it has increased awareness of - and importantly increased engagement with - exercise therapy for amputees among healthcare professionals (prosthetists and physiotherapists) and amputees themselves. This research has reached a wider audience including amputee charities and healthcare professionals, with whom we focus on mobility and movement rather than the prostheses.

2. Underpinning research

The research underpinning this case study has been led by Dr Siobhan Strike, Principal Lecturer at the University of Roehampton (from 2000), with ongoing contributions from Dr Ceri Diss, Senior Lecturer (from 2007) and Marlene Schoeman, Roehampton PhD Student (2007-2011) now at the University of the Free State, South Africa, Dr Natalie Vanicek (from 2006) initially at the University of Hull, now at the University of Sydney, and Dr Matthew Taylor, Roehampton PhD Student (2002-2008), now at the University of Essex.

Following a preliminary stage of research into biomechanics and prosthetics, a programme of research explicitly exploring the rehabilitation of lower limb amputees began in 2008, with the overarching goal of improving the functional mobility of these individuals. The specific aim of this programme was to monitor the mechanisms by which amputees achieve movement whilst compensating for their prosthetic limb. The movements studied were selected to represent daily living and exercise:

- rapid and high loading activities (running, jumping, stair descent)
- torsion activities (steering, turning)
- basic mobility (steady-state walking and stair ascent)

The findings revealed a number of mechanisms that affect amputees' ability to run, turn and jump (Schoeman et al., 2012; Strike & Taylor, 2009; Strike et al., 2012). In a study on movement asymmetry and compensations that occur when performing a countermovement vertical jump, Schoeman et al. (2012) reported high loading on the intact side and a poor contribution by the prosthetic side. Examination of running extended the previous study by exploring the mechanisms to absorb loads during the impact phase, the latter being related to long-term injury to the musculoskeletal system. We demonstrated that a shock-absorbing device developed to protect the residual limb was not consistently effective in this phase. These findings suggest that practitioners should be cautious in prescribing high-impact exercises such as jumping and running as these exert large forces on the intact and residual limbs, especially for those who have a high level of asymmetry between limbs and low strength around the hip joint. In preparation for exercise, amputees should engage in balance and strength-based low-impact exercises to improve their functioning mobility and reduce the likelihood of injury and chronic damage in sport and exercise. Research is ongoing with the prosthetic limb manufacturer (Chas A Blatchford & Sons Ltd) to enhance the shock-absorbing capacity of the prosthetic limb to optimise performance.

Research has also focussed on falling among lower limb amputees, as this is an issue of great concern for amputees and health care professionals. When assessing the biomechanical differences between amputees who fall and those who do not, we observed that amputees who have a history of falling complete movements more quickly and have reduced knee and hip strength when walking or negotiating stairs (Vanecik et al., 2009a,b). They also demonstrate poor postural awareness. We highlighted the limitations of current clinical measures used by healthcare

professionals for monitoring fall risk, fall incidence and self-perceived quality of life. Consequently the professional organisation associated with physiotherapy in amputees, the British Association of Chartered Physiotherapists in Amputee Rehabilitation (BACPAR), has begun a research programme into the monitoring and reporting of falls for amputees. A significant part of our work was performed in partnership with Chas A Blatchford & Sons Ltd, which is a leading worldwide prosthetic and orthotics company. They supported our research, providing resources 'in kind' through professional fitting and components, and facilitated MSc and PhD research (by Taylor and Schoeman, respectively).

3. References to the research

1. Schoeman M, Diss CE, Strike SC (2012) Kinetic and kinematic compensations in amputee vertical jumping. Journal of Applied Biomechanics 28, 438-447.
2. Strike SC, Wickett O, Schoeman M, Diss CE (2012) Mechanisms to absorb load in amputee running. Prosthetics and Orthotics International 36, 318-323. DOI: 10.1177/0309364612450577
3. Strike SC, Taylor, MJD (2009) The temporal-spatial and ground reaction impulses of turning gait: Is turning symmetrical? Gait & Posture 29, 597-602. doi: 10.1016/j.gaitpost.2008.12.015.
4. Vanicek N, Strike S, McNaughton L, Polman R (2009a) Postural responses to dynamic perturbations in amputee fallers vs. non-fallers: a comparative study with able-bodied subjects. Archives of Physical Medicine & Rehabilitation 90, 1018-1025. DOI: 10.1016/j.apmr.2008.12.024
5. Vanicek N, Strike S, McNaughton L, Polman R (2009b) Gait patterns in transtibial amputee fallers vs. non-fallers: biomechanical differences during level walking. Gait and Posture 29, 415-420. DOI: 10.1016/j.gaitpost.2008.10.062

All outputs have been through rigorous peer-review, and the research was supported by £3,000 of funding from the Owen Shaw Fund of the Circulation Foundation to explore the biomechanics of standing turns in transtibial amputees in 2007.

4. Details of the impact

This systematic programme of research is the first to explore how prostheses interact with functional mobility among amputees during activities other than walking. The research is furthering our knowledge and understanding of how amputees turn, negotiate stairs, jump and run, and is having a significant impact in two areas:

Impact 1: Improved prosthetic design by a leading prosthetic limb manufacturer

Our research has led to clear indications of the limitations of prostheses and the pathomechanics adopted by amputees. Identified adaptations which compensate for the lost function include the altered motion at the ankle, the reduced involvement at the residual knee, the compensatory role of the residual hip and the implications for the intact limb. The inability of the prosthetic ankle to function effectively and to allow the foot complex to absorb and return energy efficiently, both in terms of the magnitude and timing, was first identified very early in the programme of research (Strike and Hillery, 2000). Continuing this research, but focussing on recreational rather than elite athlete amputees, enabled identification of other activities that have been analysed in collaboration with our industrial partner (Blatchford). The research using the 'Tele Torsion' device, developed to absorb vertical and rotational shock, indicated that this device produced energy efficiencies in turning activities, and it was marketed worldwide on this basis. The findings fed into the development of the 'TT Pro' prosthesis, which had altered twisting angles and torsion resistance to more closely reflect the requirements of human movement. The research on dynamic activities increased our knowledge of amputee movement patterns in sport, and in turn into design requirements of the 'Elite VT', 'Echelon VT' and the forthcoming 'Elan VT' prosthetic feet/ankle complex to enhance their shock absorption capacity. The intention behind the design modifications is to adapt the magnitude and frequency of the forces and moments generated externally. Most recently, the research has highlighted the different requirements of prostheses across a range of

movement types including running, walking, standing and cornering. This research is feeding into the development of a new product by Blatchford, the 'Blade XT', which aims to enable more amputees to participate in exercise. This research approach has enabled the facility to become an internationally renowned centre specialising in amputees and exercise, and with unique experience and expertise in amputee turning and rotational biomechanics.

Impact 2: Raising Amputee and Practitioner Awareness of Exercise Therapy

In order to raise amputees' and practitioners' awareness of the role of exercise therapy for both recreationally active amputees and those who are fallers, a number of strategies were implemented. First, the research findings were fed back to the participants and the professional organisations involved (i.e. Blatchford, Clinical Provision), who in turn informed their colleagues. Second, to reach a wider audience, the authors published the findings in professional practice outlets, including non-peer reviewed articles for BACPAR (2011), a book chapter in *Ergonomics for Rehabilitation Professionals* (2009) and presentations and conferences for prosthetists through the International Society for Prosthetics and Orthotics (presentations at the ISPO triennial conference over the period) and study days (Royal Free Hospital and BACPAR).

To raise the awareness of the role of exercise therapy for amputees, and the need to engage safely in exercise, the University of Roehampton sought collaboration with Limbpower (a leading amputee charity) to promote effective participation in prescribed exercise to improve functional ability. Following a number of in-depth discussions with the charity, it was decided that producing a DVD would provide the most effective resource for amputees to observe and learn the evidence-based exercises safely and with maximum benefits, whilst avoiding potential long-term damage. The specific exercises are aimed to improve balance and proprioception and, particularly, to enable effective use of the hip musculature. The exercises are demonstrated and performed by amputees, with key pointers to ensure correct execution. The research-informed DVD has impacted on the reach of the charity by contributing to and complementing their expertise, and lends weight to the advice and support they give in reaching out to new amputees and encouraging them to exercise.

To evaluate the effectiveness of the DVD, feedback from the charity and the amputees themselves was sought. Amputees identified that the DVD gave them a good place to start exercising and removed the fear around beginning dynamic movement, which they felt might break their prosthesis or injure their intact limb and joints. Amputees also indicated that it was exactly what was needed to point them to a starting place for exercise and that it allowed them to move beyond basic rehabilitation administered in the limb fitting centres. In turn, this resulted in the research team running sessions at the Amputee Games (May 2013), where they met with the amputees, discussed their research, and evaluated the effectiveness of the DVD, receiving feedback and positive comments. Following the success of the DVD with the amputees at the games, another leading charity - The Limbless Association – has invited us to publish an article about it in a forthcoming newsletter, which has several hundred subscribers.

5. Sources to corroborate the impact

1. Saeed Zahedi, Technical Director of Chas A Blatchford and Sons Ltd. (Identifier 1).
2. Kiera Roche, Limbpower (Identifier 2).
3. DVD materials and magazine articles developed in collaboration with Limbpower.
4. E-mail feedback from users of DVD. (Identifier 3 & 4).
5. http://amputeerunningdiary.wordpress.com
6. Falls efficacy, health status and functional performance in trans-tibial amputee fallers vs. non-fallers BACPAR Journal (27/3/12).
7. *Gait and Ergonomics: Normal and Pathological in Ergonomics for Rehabilitation Professionals* edited by Shrawan Kumar (2009) CRC Press.