

Institution: Staffordshire University		
Unit of Assessment: UoA 12		
Title of case study: Foot and Footwear Biomechanics: Impact on policy, practice and standards		
Period when the underpinning research was undertaken: 2004-2019		
Details of staff conducting the underpinning research from the submitting unit:		
Names:	Roles:	Periods employed by submitting HEI:
Helen Branthwaite	Senior Lecturer	2007 – present
Nachiappan Chockalingam	Professor of Clinical Biomechanics	1998 – present
Nina Davies	Lecture in Biomechanics	2013 - present
Nicola Eddison	Senior Research Fellow	NHS Secondment (0.2FTE)
Aoife Healy	Associate Professor	2010 - present
Period when the claimed impact occurred: 1/8/13- 31/12/20		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact Our interdisciplinary research on how biomechanics, footwear, and orthotics affect foot health and foot pain has improved clinical practices and standards worldwide with: New clinical practices: Improved patient outcomes measurably by introducing plantar pressure, gait, and plantar soft tissue assessment technologies into NHS Trusts. Worked with a private UK clinic and with an Indian NGO, Mobility India, to base new services on our findings. New guidelines: Provided impetus and key evidence for new British Association of Prosthetists and Orthotists (BAPO) and College of Podiatry guidelines, covering 6m+ UK service users. Supplied foundational evidence for new global WHO standards. New practitioner training: Supplied a wide-ranging curriculum of Continuing Professional Development for BAPO. Our work is the foundation of in-house training at the international prosthetics and orthotics manufacturing company, Blatchford Limited.		
2. Underpinning research Since 2004, our interdisciplinary research team at the Centre for Biomechanics and Rehabilitation Technologies (CBRT) has worked at the intersection of engineering and health to develop assistive technology and rehabilitation solutions for foot and ankle musculoskeletal conditions. Although patients and clinicians describe foot and ankle assistive devices as alleviating discomfort and symptoms, there was no scientific consensus on these devices' biomechanical effects. Therefore, we have applied engineering methodologies to health situations to build a clear understanding of how these devices affect clinical outcomes. Our research combines design, material science, and mechanical systems approaches to examine orthoses' biomechanical effects and responses to external factors. It has three key themes: Theme 1: Addressing variations in current clinical practice and their influence on foot and ankle kinematics. Our research [3.1; 3.2] addresses a global lack of knowledge on assistive devices' biomechanical effects on patients. By combining engineering methodologies with clinical practice, we established, for the first time, the effect of simple non-moulded flat insoles on three-dimensional foot kinematics during normal walking [3.1]. We produced further research focused on testing related factors such as casting and practitioner variability, device-type (custom-made orthoses vs. prefabricated orthoses), and the midsole composition [3.2]. Our findings highlighted that patients' benefits from custom-made foot orthoses differ due to variations in practitioner knowledge and methods. They underlined the need for a more scientific approach to orthotic and footwear design. Theme 2: Understanding how footwear choice may impact foot health. Little is known about the link between foot pathologies and everyday footwear choices. We used interdisciplinary methods to investigate these links. Results from our work on young women's footwear purchases highlighted that they paid significantly less attention to long-term foot health effects than to activity-specific needs, style, and their self-image [3.3]. In the work focusing on older people's choices, our research compared dorsal pressure on and between digits and perceived comfort between off-the-shelf medical-grade shoes and participants' preferred shoes. Our findings demonstrated that these medical-grade shoes had benefits over non-medical-grade shoes and were a viable alternative to custom-made prescription footwear [3.4]. Theme 3: Identifying challenges in the NHS provision of Orthotic Services.		

A 2014 NHS report identified variances in orthotic service provision. In response, our multi-disciplinary team produced a holistic map of NHS orthotic services provision. The research documented how different service and finance models contribute to a lack of parity in orthotic service provision nationwide. It highlighted large discrepancies in service across NHS Trusts [3.5]. It showcased gaps in NHS data capture and identified a need for appropriate processes to monitor orthotic service provision quantity and quality. Similarly, our work on how UK clinicians prepare and use ankle foot orthotic-footwear combinations highlighted practitioner inexperience with the relevant three-dimensional gait analysis equipment and a widespread lack of understanding of key principles [3.6].

3. References to the research (all publications in peer reviewed Q1 journals)

- [3.1] Branthwaite HR, Payton CJ, Chockalingam N. [The effect of simple insoles on three-dimensional foot motion during normal walking](#). *Clinical Biomechanics*. 2004 Nov 1;19(9):972-7.
- [3.2] Chevalier TL, Chockalingam N. [Effects of foot orthoses: how important is the practitioner?](#) *Gait & posture*. 2012 Mar 1;35(3):383-8.
- [3.3] Branthwaite H, Chockalingam N, Grogan S, Jones M. [Footwear choices made by young women and their potential impact on foot health](#). *J Health Psychol* 2012;18:1422–31.
- [3.4] McRitchie M, Branthwaite H, Chockalingam N. [Footwear choices for painful feet – an observational study exploring footwear and foot problems in women](#). *J Foot Ankle Res* 2018;11:23.
- [3.5] Chockalingam N, Eddison N, Healy A. [Cross-sectional survey of orthotic service provision in the UK: Does where you live affect the service you receive?](#) *BMJ Open* 2019;9.
- [3.6] Eddison, N, Chockalingam, N, Osborne, S. [Ankle foot orthosis-footwear combination tuning: an investigation into common clinical practice in the United Kingdom](#). *Prosthet Orthot Int* 2015;39:126-33.

We won GBP167,632 total grant funding on four collaborative projects relating to this case study over the assessment period; Innovate UK, GBP54,254 (2013-2014); British Council (UKIERI), GBP54,378 (2017-2021); Royal College of Chiropractors, GBP15,000 (2016); WHO - ISPO - USAID cooperative agreement DFD-A-00-08-00309-00, GBP44,000 (2015).

4. Details of the impact

We have generated impacts on health practitioners and services, and on public policy and guidelines. These impacts have benefitted patients, Allied Health Professionals (AHPs), and service organisations in the UK and internationally. Many of the impacts follow from the diverse practitioner community we have built through our programme of Continuing Professional Development (CPD) including our unique MSc Clinical Biomechanics. This course was the first in the UK to offer PG training in musculoskeletal podiatry. It recruits students primarily from AHPs so that it can improve clinical practice and promote new technologies and developments. It consequently has alumni working throughout the NHS, in private practice, and in health services globally. We also use our research to drive CPD through our annual [Staffordshire Conference on Clinical Biomechanics](#) ('SCCB'). The conference is in its 19th year and is attended by over 150 people annually, who are national and international AHPs and scientists. In 2020 it was attended by 364 delegates from 28 countries. It creates discussions and provides training opportunities on clinical practice and state-of-the-art engineering methodologies including imaging techniques, mathematical and numerical modelling, and data visualisation. The conference integrated with our research and teaching, and our alumni are encouraged to return. Together, the MSc and the regular attendees of SCCB have made a community of over 900 people as students and attendees [5.1 p. 2]. This community has provided multiple pathways to impact in the assessment period.

4. 1. Impacts on Health Practitioners and Professional Services

NHS trusts, private clinics, and other foot health organisations have adopted our research. They have implemented new protocols, invested in specialised technologies, and achieved definite improvements in patient outcomes.

4. 1. 1. The NHS

We have an influential relationship with the NHS. Over 80% of our Clinical Biomechanics alumni are NHS employees. Their roles include senior, Clinical Lead positions in approximately 15 large acute and community NHS Trusts. Eddison is Clinical Lead for Orthotics Service at the Royal Wolverhampton NHS Trust, seconded to CBRT. [She is the UK's first Consultant Orthotist](#) and leads a team that handles approximately 40 referrals per day and up to 16,000 patients per year. Examples from these three NHS Trusts demonstrate our impact:

At **Central and North West London Trust (CNWL)**, the Clinical Lead for Hillingdon Community Podiatry Service is a 2005 graduate of the MSc Clinical Biomechanics and regularly attends the SCCB. She began to work with CBRT on a clinical audit in 2019 after the 17th SCCB. She reports that this collaboration has improved her knowledge and confirms the following changes:

New assessment protocols: In December 2020, Hillingdon applied our research into plantar pressure and plantar soft tissue assessments to introduce a new in-shoe pressure measurement system. This system has produced measurable improvements in patient outcomes. The Clinical Lead describes the treatment of a patient who attended Hillingdon *'42 times for redressing of a plantar foot ulcer'* in 2020. *'When he was stepped up to the Acute Clinic',* which uses pressure measurement equipment, *'he was issued with a removable casted shoe to wear. His ulcer healed within 2 weeks'*. As well as reducing healing time, CNWL testify their use of this system improves the *'clinician's knowledge and ensures patients are appropriately offloaded'*.

In addition, the Clinical Lead describes her collaboration with CBRT leading to improvements in *'operating procedures and protocols'* in CNWL's diabetes clinics and MSK Clinical Assessment and Triage services *'through [her subsequent] liaison with other managers'* [5.2].

Improved collaborative practices resulting in more effective problem solving. Hillingdon Clinical Lead offers a specific example of how the SCCB's multi-professional network gave her *'a greater understanding and appreciation of the orthotists' role'*, which gave her *'the inspiration and confidence to obtain support from the local Orthotist'* to treat a patient with cerebral palsy [5.2].

At **Leeds Trust**, our research has resulted in:

Improved podiatry services for children: The Clinical Head of Service, Podiatry and Dental at Leeds Community Healthcare Trust describes seeing *'first-hand'* how our research on children's footwear has *'supported clinicians in providing consensus based advice to parents and carers'* since 2013. As the Clinical Head writes, the Trust has *'adopted many of the [research's] recommendations in our own health care education and written literature'*.

In 2020, we brought our plantar measurement research into Leeds and Blackpool NHS Trusts. As the Clinical Head confirms, the research and its associated training programmes now serve *'a specialist clinical population of 40,000 [people as patients] and over 100 podiatrists'* [5.3].

At **Royal Wolverhampton NHS Trust** Our work has led to:

Improved Orthotics for Children with Cerebral Palsy: Eddison's research into using gait analysis to *'tune'* Ankle Foot Orthosis Footwear combinations ('AFO-FCs') [3.6] has improved the mobility of children who suffer cerebral palsy and attend the Royal Wolverhampton NHS Trust. Fine-tuned AFO-FCs have decreased patients' energy expenditure when walking by 33% and have shown measurable improvements in their hip and pelvic function and knee extension. In June 2020, the mother of a teenage patient stated, *'This treatment has enabled him to be active for longer and he has felt less fatigued, which have all helped to give him a better quality of life'*. In the same case, the patient stated the optimised AFO-FC helped him *'walk heel to toe instead of toe to heel'* and *'When I first remember wearing a splint, [because of the way it looks and how it made me walk] I felt different to other people'*, but with a fine-tuned AFO-FC, *'I just feel like it's normal for me'* [5.4].

4. 1. 2. Podiatry Clinics (Yorkshire) Ltd.

Investment in new technologies: Podiatry Clinics (Yorkshire) is a private practice based in Leeds seeing over 400 people as patients per month. It is owned by two ex-NHS podiatrists who are graduates of the MSc Clinical Biomechanics and have attended the SCCB for every year since its inception. They report *'completing the MSc and the continued relationship with CBRT have continued to help us to expand our knowledge'* and to *'progress into management positions in the NHS'*. In 2016 they left these positions to establish Podiatry Clinics (Yorkshire). Their close relationship with our research has been critical to them establishing Podiatry Clinics (Yorkshire) and using new technologies and protocols: *'CBRT's ongoing research and their annual conference have been a key part of our decisions to invest in and implement these new ways of working. We use their evidence base, and we use their innovative new approaches to plan the new directions that our business takes'*. Consequently, they offer gait analysis, Extracorporeal Shockwave Therapy, and in-house measurement and manufacture of custom orthoses [5.5].

Improved patient care: The owners used our research to maximise patient benefit in terms of treatment experience and outcomes. Their new technologies *'give us a more detailed, and more confident understanding of our patients' problems. They have enabled us to reduce patient*

treatment times (and therefore patient waiting list times), reduce patient pain, and to provide effective solutions otherwise unavailable in the Yorkshire region' [5.5].

4. 1. 3. Blatchford Limited

Influencing staff training: Blatchford is an international Prosthetics and Orthotics company with a GBP35,000,000 turnover. The current UK General Manager is a graduate of our 2010 MSc cohort, and routinely attends the SCCB and our CPD events. He has used our research to shape training throughout the company. Between 2015-2019, he was employed as Blatchford's National Clinical Lead and responsible for training the company's clinicians in new developments. He *'was therefore able to use the latest research, that I was informed of through my on-going engagement with CBRT, to inform others'* in the UK and in Norway. In 2019, as General Manager he used our research to write *'a bespoke biomechanics training module for our team'* of over 100 technicians worldwide. Prior to this module, the technician role had no standard formal qualification. *'The new module',* the General Manager writes, *'addresses this need and is underpinned by CBRT's research and my attendance at their CPD programmes'*. He has since adapted the training for wider use as *'the Biomechanics module for the Scottish Qualification Authority for technicians that provided a learning bridge for those who wanted to progress to further learning'* [5.6].

4. 1. 4. Algeos

Contributing to product strategy: Algeos is an international company that manufactures and distributes orthotics, prostheses, and other rehabilitation products. As the company's Commercial Director ('CD') writes, CBRT routinely supplies Algeos *'support and consultancy on potential commercial projects that provide a technical and clinical perspective'*. Since 2015, Algeos has used our research into the efficacy of the Optogait gait analysis system as an evidence base for marketing *'our products' effectiveness for clinical purposes to our existing and prospective customers'*. They report *'We currently have around 60 customers in the UK using Optogait'* and that their *'partner company in Italy [Microgate] has used this research to their benefit to aid in selling Optogait'*. In addition, Algeos has used CBRT research into polyurethane constructions of diabetic footwear as an evidence base to develop new products. The CD reports of Algeos using CBRT's *'work on the PU Diabetic-related materials which has allowed us to develop our offering for use in Foot Orthotics and Diabetic Footwear'* [5.7].

4. 1. 5. Mobility India

Shaping remote delivery healthcare: Mobility India is an NGO headquartered in Bangalore, India. They provide healthcare and advocacy throughout India for people with disabilities and development or rehabilitation needs. Since 2017 we have used our research methodologies and evidence base to help Mobility India redesign its service. In July 2019, Healy collaborated with Mobility India to complete a review of its prosthetic and orthotic service provision. Mobility India then used our research as the foundation of 'Tele-AT', a service for remote delivery of medical care. The NGO's Academics Director confirms Mobility India *'utilised CBRT's wide ranging work and their evidence base for using orthotic and prosthetic devices to design and shape our delivery of the "Tele-AT" telehealth service'*. Mobility India serves India's Southern, Eastern, and North-Eastern states, where 'Tele-AT' will reach all who have access to fixed or mobile internet infrastructure but are unable to access institutional healthcare services. As the Academics Director reports, the service has been designed *'to serve additionally a total of around three to four thousand people annually'* [5.8.a].

4. 2. Impacts on Public Policy, Laws, and Guidelines

Our research provides a foundation for practitioner guidelines worldwide.

4. 2. 1. The British Association of Prosthetists and Orthotists (BAPO)

Influencing new practitioner guidance: BAPO is the UK professional body for prosthetists and orthotists. As the Chair writes, BAPO used our research into the quantity, quality, and distribution of UK orthotic service provision *'as one of the key pieces of evidence for the development of our Service Provision Guidance for Prosthetic & Orthotic Services'* [5.9.a]. BAPO is a professional regulatory organisation and provides this Guidance to set the standards for NHS services. The Guidance was developed 2019-2020 and was approved in late 2020. It was published in January 2021 for wider NHS use [5.9.b]. The Chair confirms *'the document itself used research evidence from CBRT extensively'*. BAPO expect the Guidance *'will promote equity amongst the services for the wider benefit of over 6 million orthotic users in the UK'*.

Innovative CPD: In the period 2014-2016 we used our research to supply BAPO with a CPD curriculum that covered multiple topics including MSK diagnostic processes, critical appraisal

skills, diabetic foot health, and gait analysis. These one-day sessions were attended by over 200 BAPO members, as the Chair reports, and *'received excellent feedback and made a substantial impact on professional practice'* with *'evidence-based training toward providing improved outcomes for patients'*. The Chair also highlights Eddison's research (2015-) on 'tuning' AFO-FCs. Eddison's publications and presentations, she writes, *'have helped change our thought process on AFO-FC tuning and the training around that topic area'* [5.9.a].

4. 2. 2. The College of Podiatry

Contributing to Parliamentary evidence: The College of Podiatry is the UK's regulatory body for podiatrists. In 2017 it was called to give evidence to the Petitions Committee's examination of sexist workplace dress codes that require women to wear high heels. Branthwaite contributed research findings on how high heels affect the foot and lower limb, and helped compose the evidence submission. The College's Head of Policy and Public Affairs writes *'CBRT's research formed a part of key references within the College of Podiatry's submission'* [5.10.a]. The submission was published in a Parliamentary report (January 2017) and included in the Government's response on the issue [5.10.b pp. 8; 10-11].

Influencing practitioner guidance on children's podiatry: As confirmed by the Head of Policy and Public Affairs, members and alumni of CBRT play a significant role in the College's Paediatric Podiatry Special Advisory Group (PSAG) [5.10.a]. PSAG developed the College's clinical framework for paediatric podiatry in 2019, which was edited by Davies [5.10.c]. This framework helped standardise UK paediatric podiatry services. When trialled at Leeds NHS Trust, the framework improved structure, body function, and pain reduction in 71% of cases and maintained these factors in a further 21% of cases [5.10.a].

In 2018 Branthwaite contributed to PSAG's submission to the Scottish Government's Health and Social Care Directorate on suitable footwear for schoolchildren. The Head of Policy and Public Affairs writes *'The research around flexibility of a school shoe completed by Nina Davies and Dr Branthwaite was pivotal to this evidenced based document that was also easily accessible to the public in non-jargonistic language'* and that this submission *'enabled us to push forward our agendas with the Scottish Government'*. Branthwaite and Davies have since developed multiple briefing papers the College has used in discussions with the Scottish Government and with UK quangos including Public Health England and the Arthritis and Musculoskeletal Alliance [5.10.a].

4. 2. 3. The World Health Organisation (WHO)

Contributing to new global standards: Following our work on NHS provision, in 2015 the WHO mandated us to complete a formal Systematic Review of the evidence base concerning orthotics use and provision. The work was joint-funded by the WHO, the International Society for Prosthetics and Orthotics (ISPO), and USAID. The WHO used our Review as a component of the worldwide Standards for Prosthetics and Orthotics provision [5.8.b]. These Standards call for the integration of prosthetics and orthotics services into the given country's main health system and require these services to be responsive to each individual's personal and environmental needs. The Standards are being implemented in all 195 member countries, helping them to fulfil their obligations under the Convention on the Rights of Persons with Disabilities. A member of the WHO's Standards Development Group for Prosthetics and Orthotics reports that *'CBRT's work has been pivotal in these developments'* [5.8.a].

5. Sources to corroborate the impact

[5.1] Results of impact survey, MSc alumni (April 2020).

[5.2] Testimonial from Clinical Lead for Hillingdon Community Podiatry Service, CNWL Trust.

[5.3] Testimonial from Clinical Head of Service, P & D, Leeds Trust.

[5.4] ['Orthotics breakthrough helps children with Cerebral Palsy walk and play'](#) (June 2020).

[5.5] Testimonial from the owners of Podiatry Clinics (Yorkshire) Ltd.

[5.6] Testimonial from UK General Manager, Blatchford Limited.

[5.7] Testimonial from Commercial Director, Algeos.

[5.8.a] Testimonial from Academics Director, Mobility India. [5.8.b] WHO Standards for Prosthetics and Orthotics (March 2016), pages iv, 24, 43.

[5.9.a] Testimonial from Chair of BAPO. [5.9.b] BAPO Service Provision Guidance.

[5.10.a] Testimonial from Head of Policy and Public Affairs, The College of Podiatry. [5.10.b] Parliamentary report (January 2017) and Government response (March 2017) on high heels and workplace dress codes. [5.10.c] Paediatric Podiatry Clinical Framework, The College of Podiatry.