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| **Institution:** University of Southampton | | |
| **Unit of Assessment:** 03 Allied Health Professions, Dentistry, Nursing and Pharmacy | | |
| **Title of case study:** 03-04 Novel techniques pioneer global uptake of Ultrasound Imaging in Podiatry and Physiotherapy musculoskeletal services | | |
| **Period when the underpinning research was undertaken:** 2003 – 2020 | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** | **Role(s) (e.g. job title):** | **Period(s) employed by submitting HEI:** |
| Catherine Bowen | Professor of Podiatry | January 2003 – present |
| Maria Stokes | Professor of Musculoskeletal Rehabilitation | April 2004 – present |
| Nigel Arden | Professor in Rheumatic Diseases | April 2003 – present |
| Peter Worsley | Associate Professor | January 2011 – present |
| Lucy Gates | Senior Research Fellow | November 2011 – present |
| Martin Warner | Lecturer in Physiotherapy | April 2013 – present |
| Lindsey Cherry | Clinical Lecturer in Podiatric Rheumatology | January 2016 – present |
| **Period when the claimed impact occurred:** August 2013 – July 2020 | | |
| **Is this case study continued from a case study submitted in 2014?** N | | |

## 1. Summary of the impact

Musculoskeletal conditions are the leading contributor to disability worldwide. Research at the University of Southampton has pioneered ultrasound imaging (**USI**) for novel applications of musculoskeletal assessment in two allied health disciplines:

Application in the first discipline, Podiatry, has changed care pathways in practice, exemplified by a local foot and ankle diagnostic USI (DUSI) clinic shaped by our research, which since 2016 has reduced the length of care pathway from 42 to 9 weeks, and clinical visits from 6 to 2. Foot and ankle DUSI is included as a separate section in UK guidelines, and its increased uptake by podiatrists across the world is evident in Europe (6 countries), Canada, Australia, South Africa, Kenya and USA.

Application in the second discipline, Physiotherapy, has extended the scope of practice in managing challenging conditions, such as back pain, and driven clinical uptake in the UK, with even wider adoption internationally in 50 countries, notably in Europe (12 countries), Australia and USA. Physiotherapy USI research has been translated into three main clinical applications: 1) diagnostic; 2) rehabilitative (assessment and biofeedback); 3) interventional (e.g. guided needles). Novel translation has led to routine monitoring of muscle health in astronauts pre and postflight.

## 2. Underpinning research

A Global Burden of Disease study revealed that musculoskeletal conditions are the highest contributor to global disability (16% of all years lived with disability), and low back pain is the leading cause of disability (James et al 2018; *Lancet* 392:1789-858). Ultrasound imaging (USI) offers a safe, accessible, relatively inexpensive alternative to magnetic resonance imaging (MRI) for diagnosis of pathology/dysfunction. The portability of USI also permits monitoring of effects of musculoskeletal rehabilitation by allied health professionals (AHP). This has extended AHP practice to a scope previously exclusive to Medicine and has supported the health policy agenda (Department of Health 2008; Framing the Contribution of Allied Health Professionals: London).

Southampton's research uses USI for two forms of assessment: 1) diagnosis of foot and ankle musculoskeletal pathology (led by *Bowen*); 2) evaluation of skeletal muscle in terms of size (morphometry), architecture (morphology) and ability to contract (led by *Stokes*). Southampton's research has directly influenced worldwide adoption of USI into AHP clinical practice, education and research.

**Embedding Diagnostic Ultrasound Imaging in Podiatry (DUSI):** Prof Catherine Bowen's research (2003-2007) was the first to identify DUSI as an additional skill that could be used reliably by podiatrists, particularly those working in musculoskeletal health [**3.1**]. The subsequent

programme of work (2010-2017), the 'FeeTURA study' led by Bowen, involving collaboration with radiologists, rheumatologists and podiatrists from University Hospital Southampton, University of Southampton and University of Oxford, increased understanding of foot problems in rheumatic diseases. Findings indicated that foot DUSI was more beneficial than clinical examination alone, for diagnosis and implementation of effective care pathways for patients with foot symptoms and those starting biologic therapies. Further research produced diagnostic protocols for investigation of forefoot musculoskeletal pathology and validation of DUSI against MRI [**3.2**].

Bowen (Chair) established the *Osteoarthritis Research Society International (OARSI) Foot and Ankle Research Group* with Dr Lucy Gates in 2018. The Group is supported by the Centre for Sport, Exercise and Osteoarthritis Research Versus Arthritis and brings together a network of clinicians, scientists and other health professionals and key stakeholders across the world. In 2015 Bowen was awarded an NIHR Advanced Fellowship [**G1**] and funding from the Dr W.M.Scholl Podiatric R&D fund [**G2**] that enabled wider translation of the DUSI imaging protocols to produce **clinically useful definitions** of foot and ankle osteoarthritis [**3.3**].

**Providing an evidence base for Ultrasound Imaging in Physiotherapy (USI):** Identifying and retraining muscle is difficult if it is too deep to see or feel. Building on her fundamental pre-2000 research, which established USI as a powerful tool for visualising and estimating a muscle's strength from its size, Professor Maria Stokes (with Young) led the development at the University of Southampton of robust protocols for accurate assessment of specific muscles. Together with Dr Martin Warner, Dr Peter Worsley and doctoral researchers Jackie Whittaker and Sandra Agyapong-Badu, Stokes has studied technical aspects, reliability of repeated measurements and validity against the gold standard of MRI [e.g. **3.4**] and established normal reference ranges in cohorts, such as in different age groups and in the US Army. Southampton's use of USI as a research tool for investigating neuromuscular physiological mechanisms of dysfunction and recovery underpins clinical use for management of various conditions including back pain, ageing, disuse, injury and postnatal muscle dysfunction (e.g. back pain and stress incontinence) [**3.5**].

Novel applications resulting from this research include monitoring muscle size of astronauts in space and aiding their reconditioning after returning to Earth, with implications for inactive patients. In ground-breaking research by Stokes and Warner [**G3,** results embargoed], the Southampton team train astronauts at the European Space Agency (ESA) and the US National Aeronautics and Space Administration (NASA) to image each other's muscles while in space. Astronauts are measured preflight and then guided to take images inflight via direct video-link and a remote motorised ultrasound probe. Monitoring of astronauts' muscles during 6-months on the International Space Station increases knowledge of the effects of inactivity on specific muscles, which vary between individuals. Selective loss of muscle informs exercise programmes to help prevent problems such as back pain.

An international survey of use of USI by physiotherapists demonstrated how the field has evolved into several specialties from Southampton's pre-rehabilitative USI research [**3.6**]. The Physiotherapy survey has been replicated and modified for Podiatry, showing global uptake of DUSI by podiatrists as a key additional skill that benefits patients [**5.1**].

## 3. References to the research


**3.1** **Bowen C**, Dewbury K, Sampson M, Sawyer S, **Burridge J**, Edwards C, **Arden N**. Musculoskeletal ultrasound imaging of the plantar forefoot in patients with rheumatoid arthritis: Inter-observer agreement between a podiatrist and a radiologist. *J Foot Ankle Res* 2008; 1(1):5. Published 2008 Jul 28. https://doi.org/10.1186/1757-1146-1-5

**3.2** **Cherry L,** King L, Thomas M, Roemer F, Culliford D, **Bowen C, Arden N,** Edwards C. The reliability of a novel magnetic resonance imaging-based tool for the evaluation of forefoot bursae in patients with rheumatoid arthritis: the FFB score. *Rheumatol* 2014; 53(11) 2014-17. https://doi.org/10.1093/rheumatology/keu232

**3.3** **Bowen C, Gates L,** McQueen P, Daniels M, Delmestri A, Drechsler W, Stephensen D, Doherty M, **Arden N**. The natural history of radiographic first metatarsophalangeal joint osteoarthritis: a nineteen-year population based cohort study. *Arthritis Care Res* 2020 Sep;72(9):1224-1230. https://doi.org/10.1002/acr.24015

**3.4** **Worsley P**, Kitsell F, Samuel D, **Stokes M**. Validity of measuring distal vastus medialis muscle using rehabilitative ultrasound imaging versus MRI. *Man Ther* 2014; 19: 259-263. https://doi.org/10.1016/j.math.2014.02.002

**3.5** Whittaker J, Teyhen D, Elliott J, Cook K, Langevin H, Dahl H, **Stokes M**. Rehabilitative Ultrasound Imaging: Understanding the Technology and its Applications. *J Orthopaed Sports Phys Ther: Special Issue.* 2007;37(8): 435-449. https://doi.org/10.2519/jospt.2007.2350

**3.6** Ellis R, Helsby J, Naus J, Bassett S, Fernández-de-Las-Peñas C, Fernández Carnero S, Hides J, O'Sullivan C, Teyhan D, **Stokes M**, Whittaker J. Exploring the use of ultrasound imaging by physiotherapists: an international survey. *Musculoskel Sci Pract* 2020; 49: 102213 https://doi.org/10.1016/j.msksp.2020.102213

Key Grants

**G1 Bowen**, **Arden, Edwards**, Petts. Optimisation of foot care for people living with arthritis: National Institute for Health Research. (2012-16). **£468,066**.

**G2 Bowen, Arden,** Drechsler, Stephensen, Doherty. Epidemiology and lifetime risk of foot osteoarthritis and associated lower limb biomechanical factors. (2012-15). **£264,000.**

**G3 Stokes**, **Warner**. Muscle Tone in Space (Myotones) Project. ESA funded. Southampton funded by UK Space Agency / Science and Technology Facilities Council (STFC), £198,000 (2018-21), FEC for international input to project = **£50,400,000**

## 4. Details of the impact

### Embedding Diagnostic Ultrasound Imaging (DUSI) in Podiatry – *Bowen, Cherry, Gates*

Since Bowen (2008) first highlighted that podiatrists could use DUSI reliably, the technique has been widely adopted by those working within the fields of foot and ankle musculoskeletal medicine. International interdisciplinary research with New Zealand collaborators has documented that the use of DUSI by podiatrists has been expanding globally over 2012 – 2020 [**5.1, 5.2**]. Of 239 podiatrists who completed the survey and were regular users of DUSI, the majority were in Europe (UK 37%, Spain 31%, Netherlands 12%; Malta 1%; Italy 1%; Ireland 0.5%) with others from Canada (13%), Australia (4%), South Africa (0.5%), USA (0.5%) and Kenya (0.5%) [**5.1**]. The common cited benefit of using DUSI was *"improved access, reduced waiting times for appointments, and improved patient journeys through tighter, focussed management plans"* [**5.1**].

An exemplar of impact on patient care pathways is a new local Podiatry-led DUSI clinic within Solent NHS Trust primary care service (2016-present). Directly shaped by the Southampton DUSI research alongside provision of practical, face-to-face DUSI training of podiatrists (n=6), this has reduced the length of care pathway from 42 to 9 weeks, and clinician encounters from 6 to 2 [**5.3**].

As a direct result of the Southampton team's research, foot and ankle DUSI is included as a key component in national guidelines (UK North West Clinical Effectiveness Group and UK Podiatry Rheumatic Care Association, 2011; 2014; 2021 *in prep*) aimed at the management of foot health in rheumatoid arthritis and improving prognosis through early detection [**5.4**]. The guidelines continue to guide practice of the UK College of Podiatry (CoP)'s 13,000 members UK wide (NHS and independent practice) with around 350 Podiatry graduates annually. The lead author of the guidelines states, *"the guidelines are a major document used in the undergraduate and postgraduate education of podiatrists and hence enhancing the patient experience and outcome of foot health management"* [**5.4**]. Similarly, in 2017, the team led the ratification of the CoP in becoming one of six member organisations of the Consortium for the Accreditation of Sonographic Education (CASE) – a key award ensuring the legitimisation through accreditation of training programmes that develop podiatrists as safe and competent DUSI practitioners. Bowen, as Chair of the CoP Research and Development Committee, founded the CoP Special Advisory Group for DUSI with clinical researchers Dr Lindsey Cherry and Dr Charlotte Dando.

Southampton's research team continue to drive national and international initiatives to ensure the research directly informs podiatric training (pre and post-registration) and clinical practice. For example, the introduction of DUSI workshops in Malta *"has translated into circa N=70 graduate podiatrists over 10 years increasing their understanding of the use and relevance of DUSI towards improvements in the diagnosis and timely management of foot and ankle musculoskeletal problems in Malta"* [**5.5**]. In addition, Bowen gave invited keynote presentations in Singapore and Australia [**5.6**], as well as the UK, and became adjunct professor for Auckland University of

Technology (AUT), NZ and Queensland University of Technology to support their DUSI research capacity building. Regarding the *Osteoarthritis Research Society International (OARSI) Foot and Ankle Research Group* led by Bowen, AUT New Zealand Professor Keith Rome stated: *"the recently formed OARSI foot and ankle research group will allow future collaboration between the two institutes relating to DUSI and in other inflammatory arthropathies such as systemic lupus erythematous and psoriatic arthritis"* [**5.2**].

**Driving Ultrasound Imaging in Physiotherapy – *Stokes, Warner, Worsley***

Findings from University of Southampton research have led to the **translation and global take-up of USI techniques in Physiotherapy** into other areas, such as diagnostics, guiding rehabilitative and interventional techniques (e.g. guided acupuncture and injections). The work with Space Agencies (ESA, NASA [**G3**]), in particular, has raised the profile of USI in Physiotherapy.

The global reach of Southampton's research impact is best evidenced through Stokes' leading position in an **international consortium** of USI Physiotherapy experts [letters of support **5.7**-**5.9**], who established the field of **Rehabilitative USI (RUSI)** at the first RUSI Symposium in 2006 (Texas, USA) and whose most recent undertaking was the 2020 **international USI survey of physiotherapists** [**3.6**]. The 2006 symposium was led by US Army Medical Specialist Colonel Deydre S. Teyhen, who stated in 2020: *"In regards to [RUSI], it is clear from the research literature that Dr Stokes' team initiated this field of study for physical therapists. The investigative team in Southampton has conducted basic research required to validate this technology and been international thought leaders on how to apply this technology"* [**5.7**]. The lead author of the 2020 international USI survey, Dr Richard Ellis of AUT, cited [**3.5**] as "*one of the seminal publications for physiotherapy USI*", adding that "th*e different applications of USI in Physiotherapy have stemmed from the Rehabilitative Ultrasound Imaging [RUSI] field, which was greatly influenced by research from Southampton."* [**5.8**]

The international USI survey attracted more than 1,300 responses, which indicated a wide scope of practice (in terms of different applications) of USI across the Physiotherapy profession in **50 countries**. Applications include diagnosis of musculoskeletal pathology, monitoring healing after muscle trauma, biofeedback to re-educate muscle contraction and guiding needles, e.g. for acupuncture. These uses of USI result in more accurate assessment and more tailored treatment for individual patients, making treatment more effective. The survey illustrated the wide global reach of our research impact, with 60% of respondents being users in Europe, 20% in Australasia and 10% in North America. Within Europe, 47% of UK respondents were users, with higher proportions in the Netherlands (82%) and Spain (69%; where USI is already implemented in pre-registration Physiotherapy training). In Australia, 69% were USI users.

Teyhen further testified to the international reach of Southampton's research impact, stating that "*in addition to [the UK], Southampton's work helped advance RUSI for musculoskeletal medicine in the United States, Australia, and other European Countries. Their work in this field advanced physical therapy both in the civilian and military sectors… It is important to note that the gold standard techniques that previously existed were not translatable into a clinical setting. This is why this line of research has had such a huge impact around the world*."

Stokes has driven this adoption through several strands of activity within the REF impact period. She chaired the closing discussion at the second RUSI Symposium in 2016 (Madrid, Spain) to set international clinical, education and research agendas. This led the consortium to author a 2019 **International Position Statement** [**5.10**], which highlights the impact of USI use in clinical practice: "*faced with the rapid growth of USI use by physical therapists over the last decade, the profession is faced with a situation in which its traditional scope is being challenged to evolve*". The hosts of the Symposium from Acalá University, Madrid stated [**5.9**]: "*a new paradigm shift was reached, thanks to the international consensus".* Ellis asserts that this Position Statement *"is evidence of Southampton's impact that is leading regulation and policy development for physiotherapy USI …"* [**5.8**]. The position statement shows how USI protocols developed by the Southampton team are used to monitor changes in muscles due to pathology, disuse and recovery. It also illustrates eloquently how physiotherapists' use of USI has evolved from Southampton's research to **three distinct clinical applications**: 1) diagnostic; 2) rehabilitative

(RUSI; assessment and biofeedback tool to aid recovery); and 3) interventional (e.g. guided acupuncture needles and injections) [**5.10**].

These advances have translated directly to novel applications that have changed practice, and in 2018 Stokes and Warner were funded by the UK Space Agency on an international collaborative ESA-funded project (Muscle Tone in Space; Myotones Project) to monitor ESA and NASA astronauts' muscles during 6-months on the International Space Station (ISS), at a full economic cost of £50m. The head physiotherapist at ESA says: *"I use USI to assess muscle size and contraction in astronauts after a long-term stay in microgravity"* to aid their recovery [**5.11**]. This work with deconditioned astronauts also provides insight into mitigating the deconditioning effects of aging on muscles, as well as rehabilitation after periods of inactivity. Embedding USI protocols for testing muscles aided validation of *Myoton* muscle measurement technology (MyotonPRO, a non-invasive hand-held device that measures tone of superficial muscles) and thus enabled its early adoption on the ISS. **Science Minister** Sam Gyimah said: "*This pioneering space project … a great example of how we are backing science and the space sector through our modern Industrial Strategy and how, through our Ageing Society Grand Challenge, we are harnessing the power of innovation to help meet the needs of an ageing society."* [**5.12**]. Dr Libby Jackson of the **UK Space Agency (UKSA)** said the UKSA *"supports ground breaking experiments, like this one at the University of Southampton, to monitor the muscle health of astronauts … as part of our commitment to ensure Britain is a leader in space-based scientific research and innovation."* [**5.12**]. In July 2018 an **astronaut** (>1.3 million followers) tweeted and stressed in a video the **importance of monitoring** musculoskeletal health in space [**5.13**].

The **Covid-19 pandemic** required the Southampton scientists to teach and guide NASA USI specialists (novices to muscle imaging) remotely to image muscles, providing lessons for virtual guided imaging on Earth between specialist medical centres and remote clinics [**5.14**]. The Southampton course for physiotherapists was the first to be endorsed by a medical imaging body (British Medical Ultrasound Society, 2004). Teyhen states: *"Southampton's evidence-based educational courses on this topic helped ensure the highest level of science, quality, and safety were integrated into the clinical application..."* [**5.7**]. Other courses informed by Southampton's research have evolved, several by University of Southampton alumni, course attendees and research collaborators worldwide, including the UK (John Leddy), Canada (Jackie Whittaker), Australia (Julie Hides) Ireland, (Cliona O'Sullivan) and Spain (Samuel Fernández-Carnero). In Spain, the number of courses delivered across Universities and Hospitals in 2020 "*has reached 3-4 courses each weekend… recognition came from the Community of Madrid Sanitary Counsel, which approved the education and purchase of ultrasound units for Physiotherapists in Public Health Hospitals* [**5.9**]*"*.

The contribution of Southampton's extensive impact on the uptake of USI was reflected in Stokes' award of an OBE in 2018 for '*Services to Physiotherapy Research'.*

## 5. Sources to corroborate the impact

**5.1** International survey of ultrasound imaging in Podiatry.
**5.2** Letter from Professor Keith Rome, AUT New Zealand.
**5.3** Solent NHS Trust Podiatry DUSI clinical service evaluation report (2020).
**5.4** Letter from Dr Anita Williams, lead author UK NW Clinical Effectiveness Group guidelines.
**5.5** Letter from Professor Cynthia Formosa, University of Malta.
**5.6** Letter from Singapore Podiatry Association.
**5.7** Letter from Colonel Deydre S Teyhen, Walter Reed Army Institute of Research, Maryland USA.
**5.8** Letter from Dr Richard Ellis, Auckland University of Technology, New Zealand
**5.9** Letter from Dr Pecos Martin and Dr Fernandez Carnero, Acalá University, Madrid, Spain
**5.10** Whittaker JL, Ellis R, Hodges PW et al. Imaging with Ultrasound in Physical Therapy: What is the PT's scope of practice? A competency-based educational model and training recommendations. *BJSM* 2019; 0:1–7. https://doi.org/10.1136/bjsports-2018-100193
**5.11** Letter from Gunda Lambrecht, Clinical Physiotherapist, European Space Agency.
**5.12** https://www.southampton.ac.uk/news/2018/09/myotones-project.page
**5.13** Tweet: https://www.twitter.com/Astro_Alex/status/1021802302016024582 and video: https://www.myoton.com/news/myotonpro-makes-it-possible-to-test-muscle-adaptation-in-space
**5.14** Letter from Frank De Winne, European Space Agency ISS Programme Manager.