

Institution: Keele University
Unit of Assessment: UoA3 Allied Health Professions, Dentistry, Nursing and Pharmacy
<p>1. Unit context and structure, research and impact strategy</p> <p>Keele is a research-led campus-based university that combines excellence in research (REF 2014, 87% outputs rated world-leading or internationally excellent) and teaching (TEF GOLD in 2017; ranked top 3 in England for student satisfaction in 7 of the last 8 years). Health-related research is located primarily in the Faculty of Medicine and Health Sciences (FHMS), aligned with complementary strengths located in the Faculty of Natural Sciences and the Faculty of Humanities and Social Sciences. The overarching Institutes of Global Health; Sustainable Futures; Social Inclusion; and Liberal Arts and Sciences provide a framework for University-wide interdisciplinary research support.</p> <p>A recent Faculty reorganisation within Medicine & Health Sciences, including a full integration of School of Primary, Community and Social Care (SPCSC) into the School of Medicine from August 2020, has served to align staff more closely with their research foci, to strengthen interdisciplinary collaboration, foster symbiosis between research and education, and calibrate our aims in line with those of the Keele Research Strategy. This restructure saw research activity relocated from the previous Faculty research institutes (Science and Technology in Medicine; Primary Care and Health Sciences) into interdisciplinary cross-faculty themes (Musculoskeletal Health; Mental Health and Wellbeing; Regenerative Medicine; Health Professions Educational Research; Prevention, Performance and Rehabilitation; Health, Care and Wellness) to which all research-active staff are aligned, and which are hosted by academic schools. This submission draws on the research conducted within the previous research structure, the SPCSC, the School of Allied Health Professions (SAHP), the School of Pharmacy and Bioengineering (SPB), the School of Nursing and Midwifery (SNM) and members of the School of Life Sciences (SLS) working in cognate areas. Our submission to UoA3 represents a portfolio of interdisciplinary research reflecting the strategic development and expansion of research since REF 2014, which includes maintaining excellence in our musculoskeletal health and rehabilitation research, growth of activity in secondary care and prognostic research, and development of new areas of activity such as maternal health.</p> <p>A number of strategic appointments have been made in the census period to support research linked to nursing, midwifery and allied health professions. These include two readers (Hill and Wynne-Jones) and two professors (Keeley and Keeling) appointed in SNM and SAHP. To further research visibility within these Schools, we have situated responsibility for the cross-Faculty Research Themes within them; 'Prevention, performance and rehabilitation' (SAHP) and 'Health, care and wellness' (SNM).</p> <p>Working with the Faculty Research Committee, chaired by the Dean for Research, each School within the Faculty has a Director of Research to promote, develop, and coordinate research activity. Directors of Research have recently been appointed in SAHP (Hill) and SNM (Wynne-Jones). The Faculty Research Committee takes a strategic overview of staff appointments – aiming both to ensure sustainability in areas of existing research strength and to support areas of strategic development – facilities, and other research infrastructure, and has representation from each School in the Faculty.</p> <p>SPCSC has also developed a Methodology Hub – with membership from across the Faculty and from the Keele Clinical Trials Unit, the Biostatistics Group and the Keele Centre for Prognosis Research (see below) – which coordinates the provision of methodological support across Faculty research, and pursues a programme of research in methodology, data analysis (both quantitative and qualitative), and research ethics. Across the university, research is supported by the Research and Innovation Support Enhancement unit (RaISE), whose function is to provide continuous support from idea to award to delivery of research grant applications.</p>

Strategic research aims in the period 2014–2020 were to sustain national and international excellence in the following areas: Musculoskeletal health and rehabilitation; Applied clinical sciences, Pharmacology and related biomedical science; and Pharmacy.

Musculoskeletal health and rehabilitation. SPCSC hosts our world-leading interdisciplinary musculoskeletal health research theme, which draws members from across the Faculty (Belcher, Bucknall, Dziedzic, Foster, Healey, Hider, Hill, Holden (ECR), Keeley, Lewis, Muller, Paskins, Quicke, Thomas, Wilkie, and Wynne-Jones). Its work is focused on reducing the long-term disability caused by common painful musculoskeletal conditions, including musculoskeletal pain such as back pain, osteoarthritis, osteoporosis, gout, and inflammatory arthritis. We do this through a focus on the causes, consequences, prognosis, and treatment of people with these conditions, with a particular focus on developing individualized treatments. Our team comprises clinicians from the full range of disciplines involved in musculoskeletal health (AHPs, nurses, GPs, rheumatologists, pain specialists, psychologists, pharmacists) and methodologists (in our Methodology Hub) who, together, provide evidence to underpin:

- Proactive approaches to musculoskeletal healthcare, to prevent or reduce long-term disability
- Moving away from a ‘one size fits all’ model of care to one that provides tailored treatments better suited to individuals’ needs
- Development and testing of clinical interventions and new models of care that offer more accessible and holistic care for patients
- Putting patients in the driving seat, allowing them to be more actively involved in decisions about their care and better supported to maintain well-being and independence.

We have hosted the Versus Arthritis Primary Care Centre of Excellence since 2008, hold a European League Against Rheumatism (EULAR) Centre of Excellence award (with the Haywood Hospital), and are one of nine members of the NIHR School for Primary Care Research. We have published over 2500 papers in leading journals and research in primary care has attracted more than £52.5 million in research income since 2014. Our musculoskeletal research awards in the period since 2014 have included 3 NIHR Programme Grants for Applied Research (STarT MSK, PANDA-S, PROMPTT), 6 further NIHR or Versus Arthritis funded randomized trials (HIT, SCOPiC, FACTUAL, iPOPP 2, PROP OA, WAVE, RaCeR), 2 EU grants (JIGSAW E, European Institute of Innovation and Technology – Health), and 1 musculoskeletal Health Intelligence award (Nuffield Foundation). We are the only UK research team to have two (of our four to date) NIHR Senior Investigators that are AHPs (Dziedzic, Foster), two NIHR Knowledge Mobilization Fellows that are AHPs (Dziedzic, Stevenson) and two NIHR Research Professors (Foster (an AHP), Mallen (a GP)). Our musculoskeletal research team members are supported by the highest-quality external fellowships at all career levels (e.g., NIHR Clinical Research Network Research Scholarship and NIHR Integrated Clinical Academic PCAF, Clinical Doctoral Research Fellow, Clinical Lecturer, Development and Skills Enhancement award, and Senior Clinical Lecturer for our AHPs, and NIHR Clinician Scientist for one of our community rheumatologists).

Our long-standing partnerships with patients, clinicians, and policymakers, embedded patient and public involvement and engagement (PPIE), and research prioritization (e.g., hosting Critically Appraised Topic groups with AHPs, nurses, and GPs) ensure that we address questions that matter most to patients and the NHS. Our high-impact research has provided evidence on the prevalence, burden, and prognosis of musculoskeletal conditions (*Annals of the Rheumatic Diseases*, 2014; *Osteoporosis International*, 2018; *Pain*, 2016), and developed musculoskeletal outcome measures that have become widely used. For example, a new patient-reported outcome measure developed with Oxford University, the MSK HQ (*Health and Quality of Life Outcomes*, 2016) has been endorsed by NHS England, the National Rheumatology Register, the National Musculoskeletal Health Data Group, and the Chartered Society of Physiotherapy. It has been translated into 10 languages to date, with a further 7 translations pending. These findings have informed our portfolio of clinical trials, supported by our United Kingdom Clinical Research Collaboration (UKCRC) registered CTU, that have tested clinical interventions for musculoskeletal conditions, including: INSTINCTS, showing that local steroid injection leads to faster recovery of symptoms than splinting for carpal tunnel syndrome (*Lancet*, 2019); CONTACT, showing that

naproxen and low-dose colchicine produced equivalent pain relief in patients with gout, but fewer side effects with naproxen (*Annals of the Rheumatic Diseases*, 2019; impact case study 'The care and management of gout'); SUPPORT, showing the benefits of physiotherapist-led exercise for shoulder impingement and evidencing that shoulder injections do not need to be ultrasound-guided (*British Journal of Sports Medicine*, 2020); POST, showing the potential harm of case-finding for depression in patients with osteoarthritis (*Plos Medicine*, 2017); and SWAP, showing the effectiveness and value for money of brief, AHP-led vocational advice services in primary care for musculoskeletal pain (*Pain*, 2018).

We are leaders in the design, evaluation, and successful implementation of new models of musculoskeletal healthcare, including:

- *Stratified care for musculoskeletal pain* (STarT Back, IMPaCT Back, SCOPiC, STarT MSK). Our stratified care approach to low back pain (STarT Back) leads to better patient outcomes at lower cost (*Annals of Family Medicine*, 2014), is recommended by NICE (NICE 2016), NHS England (Low Back and Radicular Pain Pathway 2017), and international guidelines. STarT Back has been implemented by all West Midlands community NHS Trusts and is used across 20 countries worldwide. We are expanding stratified care based on prognosis to stratification based on response to treatment, including individual patient data (IPD) meta-analysis to identify predictors of treatment response in shoulder pain (PANDA-S programme 2018–2024), and osteoarthritis (STEER OA IPD study, 2018–2020), and are developing an online platform to support stratified care for neck and back pain (EU-BACK-UP, 2018–2020). We have undertaken a major programme of training for clinicians in the STarT Back approach, to assist them in implementing our evidence on stratified care in their practice. See impact case study: 'Implementing high-quality stratified care for low back pain.'
- *Supported self-management for osteoarthritis* (e.g. MOSAICs, JIGSAW). MOSAICs included a model primary care consultation, an Osteoarthritis Guidebook (co-produced with patients/clinicians), and an e-template embedded in the Electronic Medical Record system. It improved the quality of care and is now NICE endorsed and hosted (*Osteoarthritis Cartilage*, 2016). We lead implementation of MOSAICS internationally (JIGSAW-E, EU EIT-Health); see impact case study: 'Raising the international quality of osteoarthritis management.'
- *Better access to AHP-led care for musculoskeletal conditions*, through our series of studies testing telephone assessment and advice services (PhysioDirect), direct referral to NHS physiotherapy (STEMS, *BMJ Open*, 2014), first-contact physiotherapy in general practice (FCP evaluation) and our new programme using clinical pharmacists in general practice to support patients to reduce/stop opioids (PROMPTT programme, 2019–2023); see impact case study: 'Transforming musculoskeletal therapies and services.'
- Improved care for people with musculoskeletal pain in the context of *multi-morbidity* (e.g., ENHANCE, INCLUDE, iFRAP).

Our teams and our research findings have contributed to national and international clinical guidelines (e.g. for management of osteoarthritis, gout, back pain, and polymyalgia rheumatica). Members of SPCSC led and contributed to the important *Lancet* series on low back pain (2018). Of 66 completed or ongoing studies featured in the NIHR Themed Review of Physiotherapy for Musculoskeletal Pain 'Moving Forward' (2018), one third (22) were led by our team. A Public Health England return on investment analysis highlighted three areas of our work (stratified care for low back pain, vocational advice in primary care, and direct referral to physiotherapy) for widespread implementation.

Applied Clinical Sciences. Research in this area employs methods based on evidence synthesis, clinical trials, and epidemiological designs to improve the clinical management of patients, particularly in secondary care and the primary-secondary care interface. The Keele CTU (see below) and the Keele Centre for Prognosis Research (see below) are key to this activity. Our work here is organized in two main areas: *Evidence synthesis and large dataset research*, and *Health services research*.

Evidence synthesis and large dataset research: The major research focus is on cardiovascular disease (Ensor, Jordan, Kwok (ECR), Nolan, Mamas, Potts). We have used data from electronic

health records to study regional differences and inequalities in care of patients with cardiovascular disease. This described north-south divides in causes of mortality and morbidity accompanied by differences in health deprivation resulting in lost opportunity for reduced mortality and cost (*Lancet Public Health*, 2018). Using electronic health records from the Clinical Practice Research Datalink, we showed that 72.4% of patients presenting with chest pain in primary care do not have a cause attributed for their pain, and most do not receive any type of cardiovascular diagnosis over the next six months, yet these patients have an increased risk of cardiovascular events for at least five years (*BMJ*, 2017). In those with coronary heart disease, percutaneous coronary intervention (PCI) is the commonest mode of coronary revascularization in patients with stable angina, and gold standard for treatment of heart attacks, with 100,000 procedures undertaken in the UK annually. Using data that capture every PCI procedure undertaken in the UK over the past decade, we have shown that adoption of trans-radial access (compared with femoral access) is independently associated with significant reductions in major bleeding complications and 20–30% reductions in mortality (*Journal of the American College of Cardiology*, 2017). However, patients who mostly benefit from undergoing trans-radial access PCI, such as older people, women and complex cases, were least likely to receive it. This work revealed large regional differences in practices in the UK, with radial PCI rates varying from 20 to 80% in different strategic health authorities; this heterogeneity in practice was estimated to have resulted in 264 avoidable deaths between 2005 and 2012.

More recent work has focused on age- and sex-related differences in COVID-19 mortality (*Mayo Clinical Proceedings*, 2020) and the impact of COVID-19 on clinical outcomes (*Lancet*, 2020; *Heart*, 2020), alongside collaborative survey research with King's College London and Public Health England on attitudes to vaccination, suggesting that 64% of people in the UK would have a COVID-19 vaccination when one became available (*Human Vaccines and Immunotherapeutics*, 2020). Keele, with Imperial College, Oxford University, Leeds University and the office of National Statistics, have formed a Scientific Strategic Group reporting directly to SAGE on the impact of COVID on cardiovascular outcomes.

The research conducted within the Keele Centre for Prognosis Research in this area has led to over 200 peer-reviewed publications since 2015, including *British Medical Journal*, *Lancet*, *Lancet Public Health*, *European Heart Journal*, *Journal of the American College of Cardiology*, *Circulation*, *PLOS Medicine*, and *JACC Cardiovascular Interventions*.

A parallel programme of work focusing on *comorbidity* (Babatunde (ECR), Holden (ECR), Healey, Mamas, Wu) utilizes secondary data analysis and includes the first-ever IPD meta-analysis of exercise therapy in osteoarthritis (with data from 51 RCTs), focusing on the predictive role of comorbidities on pain and function in osteoarthritis and their role as treatment effect moderators. Other work has addressed the prognostic impact of comorbid conditions both on the management and clinical outcomes of patients with cardiovascular disease (*American Journal of Cardiology*, 2015; *Medicine*, 2016), and in relation to conditions such as diabetes, mental health, and maternal health including preeclampsia (*Diabetologia*, 2016).

Health services research: In the area of health technology, the Renal Research Group (Davies, Lambie, Sim, Solis-Trapala) is a world leader in *dialysis research*, focussing on function and injury to the peritoneal membrane. In line with its REF 2014 strategic aims, it has expanded its remit into fluid management and access to home dialysis treatment; see case study 'Improving outcomes for people on peritoneal dialysis.' The group leads the world-wide Peritoneal Dialysis Outcomes and Practice Patterns study with the Arbor Research Collaborative in Michigan USA, including the NIHR-funded UK-Catheter study, the HTA-funded BISTRO trial (assessing the value of bioimpedance to preserve residual kidney function in new haemodialysis patients; £1.3m) and is a key participant in the EU-funded Horizon2020 IMPROVE-PD project (€4m). From 2021 the group will lead the NIHR HS&DR-funded Inter-CEPt study that will develop interventions that address inequalities in access to home therapies across the country. In the area of *cancer therapy* (Brunt), recent work has focused on long-term effects of whole-breast radiotherapy (*Journal of Clinical Oncology*, 2020) and quality of life after post-mastectomy radiotherapy (*Lancet Oncology*, 2018).

Within this area of research activity there is growth in fields such as *women's health* (Keeling, Sim, Wu), *mental health* (Shepherd (ECR)), *neurological care and rehabilitation* (Hunter, Roffe, and Sim), and biochemical variables and diagnostics in *diabetes and cancer* (Fryer, Sulé-Suso, Rutter (ECR), Solis-Trapala). Current activity in neurological care is centred on optimizing treatment for acute and hyper-acute stroke and enhancing outcomes of rehabilitation with targeted and optimized therapy for people with neurological conditions. Major NIHR grants (HTA, EME and an NIHR CDRF fellowship) have supported the Stroke Oxygen Study, which was led from Keele, recruited 8,003 patients across the UK (*JAMA*, 2017) and Hunter's work (with University of East Anglia) on functional strength training in stroke (*Frontiers in Neurology – Stroke*, 2018). Developing these areas of research further is a strategic priority.

Pharmacy. Research in pharmacy centres on three principal areas. *Medicines optimization and clinical decision support:* This research theme (Chapman, Fitzpatrick, Frisher), involves prescribing analysis and developing and evaluating novel IT-based approaches to medicines optimization and clinical decision support, in collaboration with Oxford University (*BMJ Open*, 2017). Other foci are on drug use in addiction (Frisher) and antidepressants in Parkinson's disease (with psychology colleagues in the Faculty of Natural Sciences).

Pharmacoepidemiology: Frisher leads work using large databases (Clinical Practice Research Datalink, English Longitudinal Study of Ageing, The Health improvement Network database) to examine such topics as polypharmacy in relation to multimorbidity and social outcomes, alcohol consumption and health (*Lancet Public Health*, 2017), prison prescribing (*BMC Psychiatry*, 2016), and drug dependence and mental health. *New and existing pharmacy services:* With UCL and Portsmouth University, we are conducting work to evaluate a series of initiatives involving pre-registration pharmacists and GP registrars, and community pharmacists and GPs, working together to support commissioning decisions, and to evaluate interventions in community pharmacy. *Innovation in pharmacy education:* Work within the SPB 'Educational research group' is currently ongoing to develop and research the use of virtual patients (VPs) and augmented reality in education and training (Chapman, Pearson, Richardson; *Pharmacoepidemiology and Drug Safety*, 2020).

Pharmacology and related biomedical science. Research in this area focuses on the role of biochemical compounds in cells, as well as the synthesis, delivery and interaction of biomolecules in cells, using both experimental and computational modelling techniques. Staff working in this area exploit a range of multidisciplinary skills, and have diverse backgrounds – ranging from chemistry, drug discovery and pharmacy, through to biophysics and protein science – and with both academic and industrial training (linking with many pharmaceutical companies, including AstraZeneca, Johnson and Johnson, OSI Pharmaceuticals and Unilever Research). This multidisciplinary group encompasses work on both *advanced pharmaceuticals* and *novel drug delivery and application*, and comprises three professors, two readers, seven senior lecturers, and seven lecturers, and collaborates with the School of Life Sciences at Keele.

Work on *advanced pharmaceuticals* (Amith (ECR), Curtis, Davoodi (ECR), Evans, di Leva, Gates, Harper, Li, Kwong (ECR), Lima, Mennan (ECR), Morgan, Mottershead, Pearson, Reynisson, Richardson, Tonge, Wong (ECR), Wragg (ECR)) is concerned with the treatment of cancer, cardiometabolic diseases (e.g., diabetes), neural repair, and infertility. Researchers in this are affiliated to the SPB Research Groups, specifically the groups of 'Cancer' (Curtis, Davoodi, di Leva, Kwong, Reynisson, Richardson), 'Cardiorespiratory' (Harper, Wong), and 'Neurological and neural repair' (Evans, Gates, Morgan, Mottershead). Research highlights include targeted therapies that are being explored that exploit specific defects in cancer cells (i.e., their reliance on specific cell signal pathways). Studies in this area are also concerned with the synthesis and mechanism of action of novel chemotherapeutic agents, prodrugs, and proteins, as well as the advancement of drug discovery methods, and developing a better understanding of how drugs such as statins could be used to treat cancer. Work on glycobiological molecules is examining their potential role in COVID-19 therapy. Advanced methodologies are being exploited for this work, such as computer-aided drug design for molecular modelling of anti-cancer drug candidates

using density functional theory, and next-generation sequencing and bioinformatic techniques in relation to biomarker discovery.

Research being developed in the area of *novel drug delivery and application* (Curtis, Davoodi, Moss), includes the use of novel gold-iron oxide hybrid nanoparticles, macrocycle molecules, and the study of skin permeability by developing quantitative models of skin absorption. This work is additionally supported through the SPB Research Group 'Materials for biomedicine' (Davoodi, Moss). Other research foci centre on immunological molecules such as pentraxins (Greenhough), synthesis of polymeric biomaterials for drug delivery (Davoodi), the role of aluminium in brain diseases (Exley) and cellular processes in neural cultures (Evans).

Funding in these areas has been obtained from national and international, government and charitable, funders, including the BBSRC, British Heart Foundation, Dunhill Medical Trust, Egyptian Cultural Education Bureau (Egypt), European Commission, Henry Smith Trust, Higher Committee for Educational Development (Iraq), KidsCan, MRC, Ministry of Higher Education and Scientific Research (Iraq), NC3Rs, Physiological Society, Royal Society, STFC, Wellcome Trust, as well through the development of links with local charitable organizations such as the North Staffordshire Medical Institute and the Institute of Orthopaedics.

Public Involvement and Engagement (PPIE). SPCSC was an early trailblazer of PPIE and led the way nationally and internationally in this area (Dziedzic, Blackburn, Jinks, Kingstone), developing means by which patients and the public are involved in priority setting, research design, and implementation of research. We established an active Research User Group in 2006 and strategically expanded this to in excess of 135 lay members actively involved in around 130 projects. We are a National Test bed for INVOLVE Quality Standards of PPIE within the NIHR School for Primary Care Research. We offer leadership for PPIE nationally through chairing the national Research Design Service and Public Involvement Community, and in the West Midlands through leadership of the Patient and Public Involvement and Lay Accountability in Research (PILAR). Additionally, we are a member of the European League Against Rheumatism Study Group for Participation, and as a Member of the Midland Health Innovation (MHI) have been selected to lead its PPIE. Members also have leading roles in the NIHR INVOLVE Public Involvement Leads' National Group, and the Cochrane Consumers training development group. We hold membership of the European League Against Rheumatism Study Group for Participation and the Cochrane Training Development Group. We were co-applicants in the RCUK SEEK-PER study to increase the uptake of Public Engagement practices across our research.

Encouraging diversity in our Research User Group has been a strategic priority. Feedback from the Athena SWAN Charter panel particularly highlighted our support for women living with pain and arthritis to join and progress their careers as part of the PPIE team.

Open science and research integrity. This Unit is at the forefront of an open research environment; routine open-access deposition of all research outputs was embedded practice well in advance of the current REF open access policy. This Unit works with partners to seek external funding for open research publication, and where this has not been possible, utilizes Keele's research manuscript repository. This Unit has been involved in developing and implementing a research data policy for the University, and has pioneered the Keele data repository, enabling datasets to be openly available for others to re-use, as evidenced by this example (<https://researchdata.keele.ac.uk/23/>).

Our research groups strongly support open science. Specifically, we have led the international debate on transparency in prognosis research, with editorials and guidance on this and on feasibility/pilot trials published in *PLOS Medicine*, *BMJ*, and *Annals of Internal Medicine*. We have published the study protocols for our trials and large observational cohorts on open-access sites and made freely and publicly available all electronic health record clinical codelists that researchers in our research groups have derived ($n=44$). Since 2009 we have successfully operated a system of reviewed access to all anonymized datasets created and curated by SPCSC and Keele CTU. This system was chosen as an exemplar in national guidance endorsed by

multiple research funders in the UK on *Good Practice Principles for Sharing Individual Participant Data from Publicly Funded Clinical Trials* (2015). Since 2013, we have handled 32 requests for secondary analysis of these datasets from researchers based in the UK and internationally, maximizing the scientific value and impact of these data and helping to reduce waste of resources in unnecessary new data collection.

Research integrity at Keele is overseen by the Pro Vice-Chancellor for Research & Enterprise and the University Academic Lead for Research Integrity and Improvement and support from Professional Services and lead academics in each Faculty, to embed open research and research integrity principles in ongoing research strategy. This activity is recorded by Keele's publicly available annual report on research integrity; further, Keele are signatories to Concordat to Support Research Integrity (<https://www.universitiesuk.ac.uk/policy-and-analysis/reports/Documents/2019/the-concordat-to-support-research-integrity.pdf>). The strengths of leads within this Unit in terms of their contribution to the open research agenda are recognized at an international level are evidenced by the contributions to the national open data literature

Future strategic aims and goals for research and impact.

The previous REF cycle has witnessed delivery against our stated strategic aims and in doing so created an environment equipped to challenge future ambitions. To help deliver against our future strategic aims our restructure within the Faculty of Medicine and Health Sciences has positioned cross-cutting research themes synergistically and enabled a broadened future scope of the research portfolio. We have identified four strategic aims designed to cement our current research activities and position us for effective delivery across the next 5-7 years. **These are focussed on:**

- 1) provision of an enhanced environment for AHP and nursing research environment;**
- 2) supporting integration across secondary care research;**
- 3) fostering interdisciplinary research with global reach; and**
- 4) accelerating the impact of research.**

An enhanced research environment for AHP and nursing research. The School of Primary and Social Care merged with the School of Medicine from August 2020 while the School of Allied Health Professions and School of Nursing and Midwifery will remain as distinct Schools. These three interconnected hubs of expertise will benefit immediately through the creation of new staff groupings and investment in radiography, counselling, psychology and social care, where the restructure of the Faculty of Medicine and Health Sciences has emphasized the development of multi-disciplinary research. Planned growth within SNM underpins this strategic objective and is supported by the appointment of a School Research Director (Wynne-Jones, Reader in Nursing), alongside strategic professorial appointments (Keeling and Keeley). Similarly, within SAHP, the newly appointed Research Director and Reader in Physiotherapy (Hill) and new appointments in radiography (England) will be followed by further research-active recruitment, including a Professor of Cardiovascular Rehabilitation, and targets identified through a School-level research strategy. Within the newly created Methodology Hub, the Biostatistics Group and the Keele Centre for Prognosis Research, we will develop and expand our innovative and influential programme of methodological research, in particular work on qualitative methods, prognosis, meta-analysis, analysis of big data, and research ethics.

Supporting integration across secondary care research will allow us to respond to the national agenda through a greater emphasis on treatment and follow-up at the primary-secondary care interface, with opportunities for greater collaboration with our local health partners. Delivery against this aim will require a programme of recruitment to joint clinical/academic roles, which has been initiated through targeting nursing, pharmacy, and AHPs across our partner NHS Trusts including University Hospital North Midlands (UHNM), Midlands Partnership Foundation Trust (MPFT), North Staffordshire Combined Health Trust (NSCHT), and Robert Jones and Agnes Hunt (RJAH) Orthopaedic Trust. The establishment of our cross-disciplinary Research Themes – with the aim of enhancing collaborations across Schools, Faculties, and with external stakeholders, via open membership – has matched cognate interests and positioned itself as key to meeting this aim. Virtual launch events, held across 2020, drew a broad range of stakeholders where; Prevention, Performance and Rehabilitation; Musculoskeletal Health; Mental Health and

Wellbeing; and Health Professions Education Research were identified as key to the future growth and reach of AHP and Nursing research at Keele.

Fostering interdisciplinary research with global reach. The creation of the Keele Institutes for Social Inclusion; Sustainable Futures; and Global Health (led by FMHS) provide support to this aim. We seek to promote an interdisciplinary research-led agenda, matched against the development of a new BSc in Public Health, and our current partnership with Public Health England, in development of our work on public health – particularly in relation to current priorities such as COVID-19 – and health inequalities. For example, the new Institute for Global Health has created the opportunity for interdisciplinary activity in this area, and early successes have been two recent awards in 2019: a £700k grant from the MRC on schizophrenia in Pakistan and a £4M grant from the NIHR on leishmaniasis in Brazil, Ethiopia and Sri Lanka, which integrates ethnography, parasitology, and psychiatry. The pursuit of interdisciplinary research spanning biomedicine, secondary care, and population health application features as an important objective within this aim.

Acceleration of the impact of research. With support from our Impact Accelerator Unit (Director Dziedzic, physiotherapist), implementation of our health research is increasingly embedded within the whole research cycle and not seen as the end of a pipeline. Building on five submitted impact case studies to this Unit of Assessment, the Impact Accelerator Unit will continue to drive an implementation agenda with: Impact Champions across each School; a Race Equality champion to reduce inequalities and increase the diversity of our patient and public involvement and engagement; a strong Community Engagement presence in Communities of Practice for Keele Deal Health; an Interdisciplinary Think Tank to offer advice on research design and impact; and NICE Fellows and Scholars to drive quality care in practice.

2. People

Our research is delivered by academic and clinical-academic staff, professional services and support (PSS) staff and postgraduate research (PGR) students, representing a wide range of disciplines, including: physiotherapy (including two AHP NIHR Senior Investigators: Foster and Dziedzic; and an NIHR Research Professorship: Foster), occupational therapy, nursing, medicine, radiography, counselling, social sciences, social work, psychology, epidemiology, biostatistics, information science, and health services research. We have several joint appointments with local NHS clinical services – e.g., in physiotherapy, nursing, nephrology, rheumatology – that serve to anchor our research in the realities of contemporary practice.

Our staffing strategy is aligned to Keele's People Strategy and is underpinned by investment in staff development, the offer, wherever possible, of stable employment contracts, provision of flexible working arrangements, the Academic (Maternity) Returners Fund, financial support for conference attendance, and the creation and maintenance of a collegiate research culture that recognizes contribution to team science and maximizes opportunities for career progression. Our Fellowships Committee proactively identifies and supports applications to key funders. Early-career researchers, or those returning to research after a period in which they have prioritized other aspects of their role, are allocated a mentor by their School's Director of Research to advise on developing a competitive research profile and research career advancement. Keele has established a Research Leaders Network, provides a dedicated Strategic Research Leadership Programme (with Advance HE), offers coaching support for mid-career academics, and demonstrates a full and active commitment to Vitae's Concordat for Promoting Excellence in Research.

We are recognized as national leaders in primary care training. Foster is the NIHR Lead Training Advocate for Physiotherapy (2015 to date) and Chair of the HEE/NIHR Integrated Clinical Academic (ICA) Clinical Doctoral Research Fellowship (CDRF) programme for nurses, midwives, AHPs, pharmacists and clinical scientists, influencing the development of AHPs in research. Two staff in our Faculty (Foster and Mallen) were members of the NIHR strategic review of training. We also host the Wellcome Trust PhD Programme for Primary Care Clinicians in collaboration

with the Universities of Cambridge, Oxford, and Southampton (2017 to date) and are members of the ESRC North West Social Science Doctoral Training Partnership with the Universities of Lancaster, Liverpool, and Manchester.

Support for Postgraduate research students (PGRs). Our research capacity activities are supported at Institutional, Faculty and School levels across the entire spectrum of careers, from PGR students to more established researchers. Keele subscribes to the Concordat to Support the Development of Researchers. The Keele Code of Practice on Postgraduate Research Degrees is the framework through which the university delivers its postgraduate research degrees.

In addition to their School and Faculty affiliation, all PGR students are members of the newly founded *Keele Doctoral Academy*, launched in April 2020. The Academy provides a unified platform for PGR support, governance, and training, and provides opportunities for PGR students to connect with the communities of interdisciplinary researchers across the university. Such work is shared through an annual, university-wide postgraduate conference that promotes an ambitious blend of interdisciplinary original research and public engagement skills.

We provide a supportive environment for research capacity development, for 334 FTE PGR students over the census period. Success since 2014 is evidenced by: 87 successful doctoral research degree completions, which is an **average increase of 16% per staff FTE per year since REF 2014**. We deliver 92% of PGR students to completion within RCUK targets, and evidence higher scores than sector benchmarks the Postgraduate Research Experience Survey (PRES). Specifically, in the most recent PRES (response rate 63% compared to 46% nationally), Keele scored higher than the Sector benchmarks on all areas, in particular on supervision (5% above sector benchmark), research culture, research skills, and professional development, with Keele ranking 10th out of 103 HEIs in the 2019 survey. We emphasize the development of transferable skills using the nationally recognized Researcher Development Framework as a structure, and offer tailored support (e.g., mentorship and coaching, language, communication skills training).

PGR students' needs and circumstances are diverse. In recognition of this:

- We offer all funded studentships as full- or part-time (more than half of our current students are part-time); funding for these studentships comes from a range of sources and includes NIHR, Wellcome Trust, ESRC, Versus Arthritis, and the European Commission Marie Skłodowska-Curie schemes.
- We have established a fund that PhD students on internal bursaries can apply for at the end of their project if they have encountered unforeseen obstacles (taken up by 12 students, all of whom went on to successfully submit their thesis).
- We offer a limited number of salaried PhDs to healthcare professionals who wish to undertake PhDs while maintaining clinical practice (2 physiotherapists, 1 dietician, and 1 GP to date)
- Within each School there is a PGR tutor to provide pastoral care for all PGR students and extra support for any training or disability needs.
- Our staff provide formal research training modules in research methods, statistics, epidemiology, evidence-based practice, and research ethics; other relevant modules are provided by other units in the University. PGR students are also able to access our international short courses in randomized controlled trials, prognosis research, individual patient data meta-analysis, and prognostic and prediction modelling.
- Training and development plans are individually tailored, with reference to the Vitae framework, and every PGR student is provided with an annual research fund for training and conference participation.
- Students are also supported by the Keele Postgraduate Association providing social support and advice specifically for postgraduates.

There are robust procedures in place to monitor and support PGR student progress, overseen by a Faculty Postgraduate Research Committee. All students have at least two supervisors, chosen to provide both subject-matter and methodological expertise. PGR students are encouraged to gain generic as well as subject-specific skills to equip them for their future career. With support from staff, a group of PhD students have organized two national conferences in statistics, in 2015

and 2017. PGR students take a lead role in organizing the Annual Postgraduate Research Symposium, which showcases PGR research through a combination of oral presentations, posters, turbo talks and 3-minute thesis competition, with students awarded prizes for scientific quality and dissemination to a lay audience, involving our patient and public contributors. Students are also encouraged to present their work institutionally, nationally and internationally.

All doctoral supervisors are required to be research-active at the time of supervising doctoral students, undertake formal training and undergo a period of 'probationary' supervision under the guidance of an experienced supervisor. Additional training is available for supervisors around areas such as supporting student mental health.

Supporting progression and promotion of early and mid-career researchers. We have a strong track record in supporting the progression and promotion of early career researchers (ECRs), recognizing that retaining and developing the most talented ECRs in our Schools is a central part of our staffing strategy. High levels of staff retention (90%) illustrate the success of this strategy. In addition to taught modules, we offer journal clubs, internal and external seminar programmes, advanced methodology seminars (with both national and international speakers), and a series of workshops on systematic reviews and evidence synthesis. Our methodologists host several highly successful international short courses on clinical trials, prognosis research, individual patient data meta-analysis, and prediction modelling (as noted above), which are attended by postgraduate students, methodologists, and healthcare researchers from across the world. We contribute to the UK Research in Musculoskeletal Epidemiology (UK-RiME) network and mentorship programme for early career researchers, hosted by the Arthritis Research UK Centre of Excellence in Epidemiology at Manchester University.

Additional initiatives include:

- A transparent, systematic process for identifying staff for promotion based on their expertise, experience, and annual appraisal
- Increasing awareness of staff regarding the opportunities and processes for promotion, e.g. by actively encouraging staff to attend University promotion workshops
- Mentoring by senior academics to help potential applicants strengthen their CVs and plan career progression
- Formation of a dedicated Fellowships Committee, responsible for supporting personal fellowship applications through actions such as independent review and feedback on applications and CVs and convening mock interview panels with senior researchers. This Committee and a senior team have supported 44 NIHR fellowship applications (including 14 for nurses, psychologists, or allied health professionals and 10 for methodologists), of which to date 21 have been successful and 5 are pending outcome, in addition to Versus Arthritis Fellowships and ESRC funded PhDs. A successful MRC-NIHR Transitional fellowship and a NIHR Clinician Scientist award are examples of the success of this strategy.
- Making funding available for staff development, e.g. funding exchange visits with international collaborators; one-to-one mentorship and coaching
- Research-only staff are encouraged to submit for promotion to Senior Research Fellow, where the criteria focus on demonstrating excellence in research

Leadership opportunities and training. The expansion of research programmes in SPCSC, SPB, SNM, and SAHP accompanied by growth of the CTU have provided opportunities for sharing leadership functions, delegating responsibilities, and creating promotion opportunities for both research and professional services and support (PSS) staff. Staff have been supported in leadership training schemes, such as through the NIHR Academy, and the AURORA leadership development programme for women.

We aim to offer stable employment contract arrangements where possible, which is unusual in units largely funded by multiple, short-term 2- to 5-year grants. Most staff (90%) in senior positions have open-ended contracts. Among lower grades (Research Assistant to Lecturer), 39% of academic/research staff have an open-ended contract. Clinical academic staff are more likely to be on fixed-term contracts. Nearly all clinicians who are on fixed-term contracts are on research-

only contracts and have successfully applied for a clinical academic fellowship for a fixed period.

Equality and diversity. Keele University holds a Race Equality Charter Bronze award, an institutional Athena SWAN Bronze award, is a Stonewall Diversity Champion, and participates in the Disability Confidence scheme. Each of the Schools within our Faculty have an EDI Working Group, with specific responsibility for equality and diversity. SPCSC has held an Athena SWAN Silver Award continuously from September 2013 (renewed until October 2022). Feedback from the Athena SWAN Charter panel particularly highlighted our support for career development, not only for academic staff but also for PSS staff, including women living with pain and arthritis, who have been able to join and progress their careers as part of the PPIE team. The other Schools within the Faculty hold bronze awards.

Equality, Diversity & Inclusivity (EDI) working groups, whose membership reflects staff and students in terms of gender, race, and other protected characteristics, represent different levels of seniority among research and PSS staff. Complementary to these are the appointment of wellbeing champions within each of our Schools. The working groups lead on initiatives for staff and students related to: career progression and promotion; training opportunities; health and well-being at work; and awareness of EDI principles. Regular events are organized (e.g. health and well-being weeks; unconscious bias training; and seminars and workshops related to international events, such as LGBT history month, international day for Elimination of Racial Discrimination, Transgender Visibility, Women's Day, and Men's Health). Awareness and impact of these activities is periodically evaluated. The EDI Working Groups report directly to the School's Senior Management teams through the Chair of the Working Groups.

Working with the University's REF Code of Practice, we have ensured that the selection of staff and outputs has been on objective criteria, including workload allocation models, and is overseen by a committee representing all Schools in the Faculty, chaired by the PVC for Research and Enterprise. Outputs have been reviewed for submission by a minimum of two staff and those with two or more authors have been reviewed without attribution to a specific author. Staff responsible for decision-making in the REF have undergone formal training in equality, with a particular emphasis on raising awareness of unconscious bias.

3. Income, infrastructure and facilities

Our research income has almost doubled since REF 2014 (98% increase) totalling over £15.8m during this REF period. We adopted a strategy that would defocus an overreliance on a single funder through positioning our research against a wider range of priorities. In this process we were successful in developing a portfolio of research, with relevance to this UoA, spanning our interdisciplinary and impact remit. Our research grants now come from a range of sources that include NIHR, Wellcome Trust, MRC, Arthritis Research UK/Versus Arthritis, NIH and EU Horizon 2020.

Of specific note are:

- 3 NIHR Programme Grants for Applied Research: Stratified care for musculoskeletal pain (£1.9m, 2014-2019), Personalizing care for people with shoulder pain (£2.7m co-funded by Arthritis Research UK, 2018-2024), Reducing over-prescribing of opioids (£2.4m, 2019-2024)
- 5 NIHR HTA trials: Stratified care for sciatica (£1.2m, 2014-2019), Chondroitin sulphate for hand osteoarthritis (£1.1m, 2015-2020), Bioimpedance spectroscopy for renal output (£1.5m, 2016-2020), Braces for knee osteoarthritis (£1.6m, 2018-2023), Work and advice in primary care (£1.6m, 2019–2023).
- NHS Collaboration for Leadership in Applied Health Research and Care/ARC
- EU 2020 Marie Skłodowska-Curie Innovative Training Network: IMPROVE-PD (€4m)
- An MRC grant (£700k) for work on schizophrenia in Pakistan and an NIHR Global Health grant (£4M) for work on leishmaniasis, as part of a new programme of work on global and public health.

Over the same period, we have also published over 2500 papers in leading journals.

Infrastructure and facilities. Our research and infrastructure staff are co-located within purpose-built offices and laboratories found within the David Weatherall Building, the Hornbeam Building, the Jack Ashley Building, the Huxley Building, and the Guy Hilton Research Centre (on the hospital campus). The David Weatherall Building was the result of significant investment from the Wellcome, Dinwoodie and Dunhill Trusts. In 2015, Keele invested a further £3M in the extension to the David Weatherall building to accommodate the growth of SPCSC, particularly in relation to secondary care research, and Keele CTU, and offering an excellent working environment to our staff and students. Since early 2017 all staff are housed in our expanded facilities which allowed us to expand facilities for meeting rooms, offer dedicated facilities for PGR students with access to infrastructure, allocate space for a well-being room (e.g., for mothers to express milk) and staff room, and offer possibilities for stand-up working and informal meetings (meeting pods) in open plan offices.

SPCSC hosts the northern hub of the NIHR West Midlands Research Design Service (Director: Sim), providing methodological and infrastructure support to research in the region and strengthening collaborative working with clinical partners.

Methodological and infrastructure support. Several structures and mechanisms provide support through the lifecycle of research. SPCSC houses Keele's UKCRC-accredited CTU (Director: Lancaster). The CTU has 30.7 FTE staff, is currently supporting 38 trials across both primary and secondary care and receives NIHR support funding in recognition of its NIHR portfolio.

Alongside this is the Faculty's *Methodology Hub*, which brings together methodological expertise within the Faculty. Within the Hub, the *Biostatistics Group* comprises four professors, one reader, three senior lecturers and 12 additional academic staff. It provides statistical support within the research foci in this UoA, with members of the group integrated within the respective research teams. Additionally, it is has strongly involved in methodological research and innovation, with specific interests in prognostic research, survival analysis and meta-analysis (Riley, Blagojevic-Bucknall), analysis of big data (Jordan), clinimetrics (Lancaster, McCray, Muller), clinical trials methodology (Lewis, Sim), multivariate modelling (Solis-Trapala), research ethics (Sim) and pilot and feasibility studies (Lancaster [founding editor-in-chief of the BMC journal *Pilot and Feasibility Studies*], Lewis, Sim). A growing programme of research in qualitative and mixed methods, in conjunction with Queen Margaret University and the University of Oslo, is underway, focusing on issues such as saturation, sample size in interview studies, focus group methodology, and metasynthesis (Kingstone, Saunders, Sim).

The *Keele Centre for Prognosis Research* supports our evidence synthesis and large dataset research by leveraging its statistical and prognosis research expertise to develop a programme of work around real-world evidence synthesis using data derived from primary, secondary and tertiary care. It focuses on using routinely collected "big data" from national cohorts of patients to improve clinical outcomes. To this end, the Centre utilizes large, comprehensive national (e.g., Clinical Practice Research Datalink (CPRD)) and international (e.g., the US National Inpatient Sample) databases to support its research. We have invested in a Gold CPRD/ARUM licence and have appointed a specialist data manager to oversee and manage the large and complex datasets used. Three members of the Centre are part of the MRC PROGNosis REsearch Strategy (PROGRESS) partnership, and methodologists within our Methodology Hub run several two-to-four-day international courses on clinical trials, individual patient data meta-analysis, prognosis research, and predictive modelling, attracting participants from across the world.

Laboratory infrastructure support.

Following on from REF2014, Keele University has made major investments in the campus facilities that house pharmacology and related biomedical science research. These were largely realized through a £45M campus-wide investment delivering a **new Central Sciences Laboratory (£34M, including £2M of capital investment in equipment)** opened in 2019, a unique facility that brings together different disciplines, including chemistry, physics, pharmacy and geology. This new facility is complemented by an ongoing refurbishment programme of the **Lennard-Jones**

laboratory (£7.2M). This has already resulted in the repurposing of former teaching facilities, for example a laboratory being converted to a research space with 20 fume hoods. The new **David Attenborough Laboratories** (£11M) were opened in 2019, doubling the existing laboratory space available for laboratory, including pharmacy, research. Keele and the Unit are committed to identifying and addressing challenges related to inequality and to ensure equal access to all our facilities and support structures.

Researchers in the Unit have access to facilities commensurate with the needs of our research. These include access to material production facilities such as vacuum-based materials deposition, hydrothermal synthesis, dedicated furnace room, and glove box facility for handling air- and moisture-sensitive materials, as well as biomaterials production such as 3D printers and nanoparticle formulation. These production facilities are supported by a suite of materials characterization techniques including NMR facilities (equipped for both solution and solid state), XRD facilities for single crystal and powder diffraction work, electron microscopy, Inductively Coupled Plasma Spectrometers (ICPMSs) and a wide range of mass spectrometry equipment, including low- and high-mass resolution analysers, with technical support for instrument maintenance and development. In addition, specialist facilities are available for nanoparticle analysis (e.g. Zetasizers, AC susceptometry, Faraday microscopy), as well as gas and breath analysis (SIFT-MS).

Biological characterization equipment includes flow cytometry (FACSCANTO II, BD Biosciences), genomic and proteomic analysis (including high-throughput techniques such as gene arrays, PCR and mass spectrometry). Bio-imaging modalities include fully automated long-term life cell tracking microscopy (Cell-IQ), atomic force microscopy (Bioscope Catalyst), confocal microscopy (including an Olympus FV1200), confocal Raman microscopy (ThermoFisher DXR2), micro-CT (Scanco), biological electron microscopy (scanning and transmission) and optical coherence tomography. Healthcare-related research benefits from direct links with the medical community. The Guy Hilton Research Centre (GHRC) is a purpose-built research facility, in close proximity to the Royal Stoke Hospital. Opened in 2008, the GHRC gives researchers access to GMP-grade clean rooms, patient assessment rooms, a laser laboratory with high-spec optical benches and a magnetism laboratory with a suite of magnetic materials preparation and analysis facilities.

Researchers within the Unit share facilities with other HEIs and make extensive use of major national and international research facilities. Keele has established a formal partnership with the University of Liverpool's Technology Directorate (TD), enabling Keele researchers to access specialist facilities, associated equipment and expert staff across a range of biomedical science-related areas. So far, this has generated £1.9M of income from RCUK (now UKRI), shared with the TD. In 2017 Keele was invited to become a member of Midlands Innovation, a partnership of 8 research-intensive universities in the Midlands with a remit to power growth in the region. One result of this partnership is Midlands Health Innovation, which combines the 7 partners hosting medical schools and aims to share mass spectrometry and medical imaging facilities, for example, and facilitate collaborative grant applications. This allowed cross-consortium support for two BBSRC Alert equipment awards with the University of Liverpool Institute of Integrative Biology (2016 and 2018). Major research facilities used in the census period include the Diamond Light Source (DLS), ISIS neutron source and the European Synchrotron Facility (Grenoble), the ALBA synchrotron facility (Barcelona) and the Advanced Light Source (Berkeley, USA). Research active staff in both this and our closely aligned UoA12 General Engineering submissions are active in managing these facilities, such as Telling (DLS Chair of beamline I08 working group, DLS User Group lead for Imaging and microscopy), Sulé-Suso (DLS user working group soft condensed matter), and Hollamby (ISIS facility access panel).

Knowledge mobilization and research impact. A dedicated *Impact Accelerator Unit* (IAU) was established in 2015 to have a positive and sustained impact on public health, health and social care, by supporting timely movement of Keele's health research into practice, with a strong emphasis on rehabilitation and primary care. The IAU is led by Dziedzic (Arthritis Research UK Professor of Musculoskeletal Therapies, NIHR Senior Investigator, and NIHR Knowledge Mobilization Fellow) with a core team covering engagement and partnerships, clinical leadership

and expertise, clinical champions (e.g., NICE Fellows), Q Community membership, project management and coordination, and health informatics. Strong representation of patients and members of the public is ensured through a dedicated PPIE group for knowledge mobilization called the LINK group (Lay Involvement in Knowledge Mobilization). The IAU's activity reflects both stakeholder-led and strategic, co-created priorities and draws on extensive regional, national, and international networks and collaborations (see Section 4). Included among priority projects undertaken by the IAU since 2015 are the successful implementation regionally, nationally and internationally of Keele's STarT Back stratified care approach for low back pain (impact case study: 'Implementing high-quality stratified care for low back pain') and core management of osteoarthritis in primary care (impact case study: 'Raising the international quality of osteoarthritis management').

The IAU has a leading role in closing the evidence-to-practice gap, by accelerating both the uptake and impact of research evidence. By working with stakeholders to create innovations that arise from research, and offering solutions to our partners' problems, we are able to ensure that there is a positive and sustained impact on public health, and health and social care – maximizing the benefits of world-leading health and social care research to improve the quality of life for patients and the public.

The IAU adopts two key approaches to identifying and aligning our priorities: stakeholder-led response mode and strategic, co-created priorities. The overarching objective is to have a positive and sustained impact on public health, health and social care, by supporting the timely movement of Keele's health research into practice, with a strong emphasis on primary care. Our activities are centred on:

- implementation of the best health research
- co-creating transformation to increase the quality of care
- development of impact case studies
- leading multi-disciplinary evidence-based practice groups
- designing and delivering knowledge mobilization within research programmes
- maintaining the patient voice as an integral part of knowledge brokering
- securing and delivering a strong portfolio of externally funded activity
- developing the next generation of knowledge mobilization leaders

Our IAU is part of the West Midlands Knowledge Mobilization Collaboration, a partnership between knowledge mobilization colleagues at Keele University, Birmingham City University, Warwick University and the Collaboration for Leadership in Applied Health Research and Care (CLAHRC) West Midlands.

We have diversified the portfolio of our research and innovation through access to different sources of funding, e.g., the IAU was awarded one of the UK's first European Institute of Innovation and Technology innovation grants, now cited as an implementation success story for Europe, and leads the implementation of management programme for the Joint Effort Initiative (Osteoarthritis Research Society International). The Director of the IAU (Dziedzic) is seconded part-time to NICE to support their Fellows and Scholars Programme as an implementation adviser. She is also on the board of the West Midlands Academic Health Science Network.

4. Collaboration and contribution to the research base, economy and society

Collaborations:

We attract world-leading collaborations, which are an integral part of our research and impact strategy and its successful delivery, across all elements of our research profile. In our musculoskeletal research programme. Visiting Professors from Sweden (Pettersson), Norway (Grotle), and Australia (Menz) provide additional expertise, facilitate integration of international data resources, and provide staff training. Collaborations have led to: high-impact publications, including the 2018 *Lancet* Back Pain Series; international comparisons of primary care musculoskeletal consultation (*Annals of the Rheumatic Diseases*, 2014); successful grant applications on stratified care (Australia: NHMRC 2018–2022; Norway: Norwegian Research

Council, 2020–2024; USA: PCORI MATCH study 2013–2015), and international delivery of our prognosis course (Norway, 2020). Formal collaborations with Southampton (Walker-Bone) have resulted in the successful renewal (2019) of the MRC/Versus Arthritis Centre for Musculoskeletal Health and Work. We have built strong collaborations to grow primary care research in Asia (Sri Lanka, Pakistan, Philippines, Malaysia, Singapore), Africa (Zambia, Ethiopia), and South America (Brazil). National and international collaborations allow us to share methodological expertise, ensure innovation, and increase research impact.

Our long-standing strategic collaboration with Birmingham University's Health Economics Research Unit (2008 to date) ensures high-quality health economic input in our research. In leading the long-term conditions theme of the NIHR West Midlands Collaboration for Leadership in Applied Health Research and Care (CLAHRC; now 'Applied Research Collaboration', renewed in 2019-2024), we work closely with academic researchers from a wide range of disciplines at Warwick and Birmingham Universities. Our prognosis research team collaborate closely with world-leading researchers (e.g., Moons and Debray, Utrecht; Steyerberg, Rotterdam; Hayden, Halifax, Nova Scotia). This collaboration, supported initially by a prestigious MRC Partnership Grant, produced a highly influential framework for prognosis research, reporting guidelines and risk-of-bias tools, and a textbook (*Prognosis Research in Health Care*, 2019, Oxford University Press). In nephrology, we have collaborated with an international consortium in producing a recently published strategic plan for integrated care of patients with kidney failure (*Kidney International*, 2020), and Davies is lead for the International Society for Peritoneal Dialysis/Arbor Research Collaborative and works with the University of Washington and the IMPROVE-PD Consortium. In neurorehabilitation, Hunter collaborates with the University of South Australia, Adelaide and the Neuroscience Research Australia (NeuRA), Sydney, in addition to joint work with the University of East Anglia. Our work on COVID-19 involves collaboration with Imperial College, King's College London, Oxford University, Leeds University and the Federal University of São Paulo.

We have developed strong local and regional links with the NHS, and we have joint appointments in areas such as physiotherapy, nursing, nephrology, rheumatology and mental health. Through these partnerships we have provided evidence-based training to support new practitioner roles linked to local priorities and initiatives, including first-contact practitioners and social prescribing. Some of the tangible benefits of these collaborations include:

- Uptake of our STarT Back intervention by all community physiotherapy providers in the West Midlands (supported by a collaboration between Versus Arthritis, Keele and the West Midlands Academic Health Science Network).
- Early adoption of physiotherapy direct/self-referral to physiotherapy – a precursor to the national First-Contact Practitioner Scheme.
- The decision by Staffordshire STP to act as a beacon site for the adoption of NIHR Moving Forward evidence-based interventions, supported by a collaboration between Keele and the Chartered Society of Physiotherapy.
- Developing evidence-informed strategies to meet the mental health needs of people living with persistent pain, supported through the Q Lab–Health Foundation.
- Some of the highest primary care study accruals for West Midlands North Clinical Research Network.

Each year we host 10–20 research visits from international HEIs, many of whom are early career researchers attracted by our reputation for applied health care research and a culture of open collaboration.

Pharmacy and pharmacy-related biomedical research have an extensive national and international collaborative profile. Key, long-standing, national collaboration partners are drawn from Aston, Cardiff, Glasgow, Hertfordshire, Liverpool, UCL, Nottingham, and Newcastle Universities, along with the National Institute for Biological Standards and Control and Public Health England. International partnerships include: Europe: Julius-von-Sachs Institute (Germany), Nencki Institute (Poland), Rozoni Instituto (Italy), University of Copenhagen (Denmark), Vrije Universiteit Brussel (Belgium); USA (Carnegie Mellon, North Carolina); Brazil (Federal University

of Parana, Federal University of Sao Paulo); Iran (Royan Institute); Australia (University of New South Wales); and New Zealand (University of Otago, University of Wellington). An exemplar of our approach to global health research is the growth of a collaboration with the University of Mauritius led by Wen Wu Li. With Royal Society and Tertiary Education Commission (Mauritius), this collaboration offers support to PhD students, in Mauritius, exploring endemic medicinal plant properties. This wide range of partnerships is complemented by the unique collaboration between Richardson and the British Pharmacological Society to develop the whydoscientists.org platform, which is a public-facing, scientist motivation exploring, resource.

Leadership

Our staff have leadership roles in research funding bodies (NIHR Programme Grants; NIHR RfPB West Midlands) and professional societies, such as: British Pain Society (Ashworth, Sowden); UK Spine Societies Board and Society for Back Pain Research (Foster); Society for Academic Primary Care (Chair: Chew-Graham); Versus Arthritis clinical champion (Stevenson); national implementation lead for musculoskeletal physiotherapy for NIHR Dissemination, national leadership of the NHSE Midlands Musculoskeletal Network (Dziedzic). We initiated the West Midlands NIHR CLAHRC Knowledge Mobilization Research Forum and contribute to the National Forum, the NIHR Knowledge Mobilization Alliance. We facilitated a workshop for the launch of the NIHR Themed Review on Musculoskeletal Physiotherapy for 90 stakeholders from a range of professional backgrounds and helped the NIHR gain an understanding of knowledge mobilization for a report for the NIHR Strategy Board (July 2018), describing enhanced dissemination activity. Our commitment to NIHR is also demonstrated through established roles, e.g., from 2012–2014 the Specialty Lead for Musculoskeletal in the West Midlands (WM) Clinical Research Network, and for the national group we initiated the first patient and public involvement (PPI) membership on the Specialty Panel.

Further to the above, staff returned within this submission have key national and international roles in societies relevant to the biomedical sciences and beyond. These include Athena SWAN (Chair and panellist for National awards), Brazilian Academy of Science (Fellow), Brazilian Society for the Advancement of Science (Editorial Board), International Society for Clinical Spectroscopy (founding member), International Society for Thrombosis and Haemostasis (Diversity, Equity and Inclusion task force co-lead), Manchester RNA Salon (organizer), Midlands UK Protein Crystallography consortium Diamond BAG (PI), Northwest Proteoglycan consortium (Chair), Physiological Society (Trustee, Council member, and Chair of the Membership and Grants Committee), RNA Society (Chair in Business Development), and The Platelet Society (Treasurer and Executive Committee member).

Davies received the Oreopoulos Life-Time achievement award for contributions to Peritoneal Dialysis in 2018. He chairs the International Society of Peritoneal Dialysis (ISPD) publication committee and is Associate Editor of *Peritoneal Dialysis International*. He is president of Euro-PD, co-chairing the joint ISPD-EuroPD meeting in Glasgow, 2021. Davies is also co-chair of the International Society of Nephrology's Kidney Failure Initiative and chairs the society's dialysis work-group. Lambie chairs the Kidney Research UK Peritoneal Dialysis study group and is a member of their research awards committee. Gilchrist is Associate Editor for *BMC Pediatrics*, Academic Lead for Paediatrics, Trustee at the British Lung Foundation, Paediatric Director of North West Midlands Cystic Fibrosis Centre. Sim is a statistical editor for *BMC Musculoskeletal Disorders*.

Further leadership is evident through staff contributions to sustaining vibrancy across a range of publications spanning the pharmacy and pharmacy-related biosciences. These include editorial board positions on *Antibiotics*; *Biomarkers*; *BioMed Research International*; *Diseases*; *Experimental and Therapeutic Medicine*; *Frontiers in Endocrinology*; *International Journal of Cosmetic Science*; *Journal of Pharmacy and Pharmacology*; *Noncoding RNA*; *Oncology Letters*; and *Pharmaceutical Frontiers*. Staff are also section editors of *F1000*, and *Pharmaceutics*, and guest editors of *Frontiers in Cardiovascular Medicine*, *Molecules*; and *Polymers*, and associate editors of *Biochemistry and Cell Biology* and *Micro and Nano Letters*.

Sim and Lewis sit on NIHR and Health and Care Research Wales research funding panels, Babatunde, Bucknall, Hunter and White sit on the West Midlands Research for Patient Benefit funding panel, and one or more individuals sit on each of the NIHR HTA, HSDR and PGfAR funding boards, as well as on HTA prioritization committees. Sim is a member of REF2021 sub-panel 3.

Implementation and impact:

We actively encourage involvement with NICE as a means of accelerating impact of research in guidelines, and have supported three NICE Fellows (Dziedzic, Sowden, Salt), and membership of Guideline Development Groups (GDGs) – low back pain (Somerville) multimorbidity and depression (Chew-Graham), workplace health (Wynne-Jones) and osteoarthritis (Cottrell, Quicke, Parry). We are represented on NICE's Quality Standards Group (Walsh) and offer implementation advice as an Adviser to the NICE Fellows and Scholars Programme (Dziedzic).

We are active in promoting musculoskeletal health within our public health contract and advise Public Health England on the uptake of their top Musculoskeletal Interventions for Implementation. Additionally, we have worked with the Faculty of Occupational Medicine of the Royal College of Physicians to produce guidance for practitioners on return to work for patients with long-COVID.

Industry engagement is enhanced by our track record in taking a leading role in NIHR's contribution to growth through our Impact Accelerator Unit and leadership of the Midlands Musculoskeletal Network. Our work with Public Health England has demonstrated the return on investment for key interventions being implemented in primary care (STarT Back £226.23 per £1 investment; PhysioDirect £47.32 per £1 investment; Vocational Advice £11.13 per £1 investment).

We have contributed to growth through leadership of the West Midlands Musculoskeletal Specialty Portfolio, with some of the highest accruals for primary care. Working with the West Midlands Academic Health Sciences Network, we have shaped musculoskeletal calls for the Small Business Research Initiative (SBRI) and hosted an EIT-Health Innovation by Ideas project (JIGSAW-E). The SBRI Healthcare process is built around defined competitions. We have previously led a successful musculoskeletal call for the West Midlands Academic Health Science Network, and we have launched a new initiative on 'Improving Outcomes in Musculoskeletal Disorders'. The SBRI is a well-established body supporting companies to generate economic growth and enabling improvement in achieving government objectives. It supports economic growth and enables the development of innovative products and services through the public procurement of research and development. We have used our research evidence to inform the SBRI themed call and have championed themes on: self-care and preventative interventions; efficiencies in delivering care; and scaling up the use of regenerative medicine (Dziedzic, Roberts, Hill). £4m has been given to successful SMEs in 2019.

Working with the West Midlands Academic Health Science Network, Keele University is a named linked third-party member of the European Institute of Innovation and Technology – Health (EIT-Health). In the UK we are partnering with Lloyds Pharmacy to implement our innovations into community pharmacies. EIT Health funding offers EU citizens greater opportunities to enjoy a healthier and active life for longer, and to postpone dependency on others, by leveraging big data and new technologies, identifying and removing barriers to innovation, and building on education and talent creation.