Institution: Teesside University
Unit of Assessment: 3 Allied Health Professions, Dentistry, Nursing, and Pharmacy
1. Unit context and structure, research and impact strategy

Unit context and structure

Our Allied Health Professions, Dentistry, Nursing, and Pharmacy unit (60.5 FTE) comprises 65 researchers from the School of Health and Life Sciences. Our research is organised through three research centres focused on rehabilitation, public health, and biosciences (through the recently formed National Horizon Centre).

The Centre for Rehabilitation (led by Martin) includes 24.8 FTE staff, five graduate tutors and 31 PhD students. Our work is informed by our specific methodological research and expertise including: physical, physiological, and psychosocial measurement; behavioural intervention development; evaluation and optimisation; systematic reviewing and meta-analysis; research design and statistical analysis; healthcare user experience and education; and technology development and application. Research takes place across three themes: Management and Prevention of Long-Term Conditions (led by Ryan and Harrison); Physical Activity, Exercise and Health Outcomes (led by Batterham and Atkinson); and Applied Health Psychology (led by Avery and Flynn). Our industry-facing research and innovation is delivered through the Health Innovation Centre (HIC); established in 2017 to develop health technologies as part of a formal partnership with independent research and technology organisation TWI. The HIC is part of TWI's network, which includes 12 innovation centres, the National Digital Catapult and the National Structural Integrity Research Centre.

The Centre for Public Health (led by Zohoori) includes 13.7 FTE staff, five graduate tutors, and 11 PhD students. Research focuses on: behaviour change; children and young people's health; e-health; nursing; nutrition and dietetics; obesity and obesogenic environments; oral health; physical activity; and the clustering of health risk behaviours. This work is underpinned by: methodological expertise in qualitative and quantitative research methods; systematic reviewing; service evaluation; intervention development; co-production; and embedded research. Research takes place across two themes: Public Health Interventions and Disease Prevention (led by Giles and Nnyanzi); and Translational Public Health (led by Lake and van der Graaf). We have long-standing collaborative relationships with the World Health Organization (WHO) and Public Health England (PHE), as well as partnerships within regional and national infrastructures, such as Fuse (the Centre for Translational Research in Public Health), the National Institute for Health Research (NIHR) School for Public Health Research (SPHR), and the NIHR Applied Research Collaboration for the North East and North Cumbria (ARC NE&NC) (see section 4).

The National Horizon Centre (NHC) is a centre of excellence for the bioscience industries (led by Rand). It includes 22 FTE, seven graduate tutors and 17 PhD students. Research explores the characterisation, understanding, and modelling of complex interactions within biological systems. This work includes the study of: cancer and other diseases; food technology; development of medical diagnostic devices; ecology and environment; forensic archaeology; and biotechnology enhancement. Research takes place across four themes: Health and Disease (led by Ortiz); Bioinformatics and Data Science (led by Li); Biotechnology and Analytics (led by Mina); and Sustainable Planet (led by Bojko). The NHC is situated in a £22m purpose-built facility, opened in October 2019. Our multidisciplinary team of researchers works in partnership with industry, the NHS, and other stakeholders. NHC is a designated National Training Centre for the Advanced Therapies Skills Training Network. It is part of the Northern Bio-Accelerator Partnership (NBioP), a

collaboration with the Centre for Process Innovation and Fujifilm Diosynth Biotechnologies to accelerate the bioscience sector in the Tees Valley through the creation of a bioprocessing, biomanufacturing and biopharmaceutical hub.

The multidisciplinary nature of our research base means that our staff collaborate across centres, between research themes and through the university's three research grand challenge themes (creating vibrant, cohesive and resilient and societies; forging a smarter, greener industrial economy; and shaping the future of health, care and wellbeing), which drive institutional research priorities aligned to regional growth, the UK's industrial strategy and the UN's sustainable development goals.

Research and impact strategy

Research strategy

The university's strategy for 2015-20 (Teesside 2020) reconfigured school structures to bring together compatible disciplines and facilities (in our case biosciences with health in the School of Health and Life Sciences). As part of Teesside 2020, and in partnership with the Tees Valley Combined Authority (TVCA), the university developed the £22m NHC (funded by European Regional Development Fund and TVCA) to drive economic growth in the Tees Valley through collaborative research and innovation in the biosciences.

Our unit strategy in REF2014 set out to grow research aligned to our core academic functions through strengthening sustainability, building capacity and improving research quality; and by investing in our research base, developing our researchers and securing additional research funding.

Since 2014, we have integrated biosciences research with our rehabilitation and public-health themes by: creating a new school structure; refreshing our research centres; appointing 17 bioscience researchers and four graduate tutors; and investing in the University Alliance (UA) Doctoral Training Alliance (DTA) in biosciences for health. Staff with Significant Responsibility for Research (SRfR) have increased to 60.5 FTE, through mentoring and development of existing staff, and investing in 36.2 FTE posts (in biosciences, bioinformatics, health psychology, environmental impact, food science/nutrition). We have grown our research income by 39 per cent: from an average of £657,000 a year in the REF2014 period to an average of £914,000 a year in REF2021. We achieved this through industry collaborations funded by the EU and Innovate UK, and projects with health-sector partners funded by NIHR and UK research councils (see section 3).

New and developing staff are supported to improve the quality of their research by a process of mentoring, training and peer review, enabling them to build their research networks and develop their publication records (see section 2). We have seen the benefit of this in increased publications from existing staff not submitted in 2014 and the increased value of bids made. In 2017, bids made had a total value £2.0m. In 2020, we submitted bids with a total value of £13.6m.

We have grown our postgraduate community by recruiting 116 PhD students and delivering 6.9 completions a year on average over the period (compared with an average of 4.9 in REF2014), with the help of a £3.5m university investment in 52 PhD studentships, including 16 graduate tutors.

We have facilitated industry engagement, partnerships and collaborations to support future impact through the HIC and strategic partnerships with Fujifilm Diosynth Biotechnologies, and the Durham Tees Valley Research Alliance (DTVRA), which brings together County Durham and Darlington, North Tees and Hartlepool and South Tees Hospitals NHS Foundation Trusts.

Impact Strategy

We have continued our focus on applied research and co-production methodologies to ensure that our research addresses sector challenges, meeting health needs at regional, national, and international levels. Specifically, our strategy has sought to: develop and provide robust evidence, and open and accessible datasets, that are aligned to the needs of clinicians and policymakers to support, or make changes to, both healthcare policy and practice; work closely with stakeholders and beneficiaries across the research lifecycle to ensure research outcomes are embedded and realised; and develop tools and digital technologies that enhance and transform the working practices of our partners in health and sport, producing new insights and new ways of working.

Staff are mentored and trained in research design, stakeholder mapping and theories of change. This approach is supported by work-based learning and our participation in, and contribution to, established and emerging collaborative endeavours that bring together researchers, policymakers, and healthcare professionals. Our strategy has led to the formalisation of relationships with the region's NHS trusts through memoranda of understanding, and engagement with DTVRA to support co-production of research. Our on-going membership and contribution to Fuse, a virtual research centre that brings together the five north-east universities (Durham, Newcastle, Northumbria, Sunderland, and Teesside), has facilitated further the co-production of research and its translation into impact. Fuse's mission is to transform health and wellbeing and reduce health inequalities through public-health research and value-for-money policy and practice. We lead the Translational Research programme within Fuse and manage the innovative AskFuse service, a rapid response and evaluation service for collaborative research projects with practitioners, policymakers and local communities (van der Graaf).

In spring 2020, we contributed to the formation of the ARC NE&NC, a partnership of six regional universities, the NHS, health and social care providers, local authorities, the voluntary sector, community groups, members of the public and others to deliver better, fairer health and care at all ages and in all places. Our on-going participation in this collaborative endeavour strengthens our engagement with key stakeholders and the impact of our research. Work is based around seven research themes: Martin leads the Integrating Physical Health, Mental Health and Social Care theme and van der Graaf is deputy lead for the Knowledge Mobilisation and Implementation Science theme.

Our strategy has facilitated knowledge exchange and commercialisation by accessing dedicated professional support and pump-priming funding (HEIF) from the Department of Academic Enterprise (DAE) and committing £300,000 to establish the HIC in 2017. As our unit has evolved to incorporate biosciences, we appointed a principal lecturer for enterprise and business engagement at NHC (Akram) and a DAE business innovation manager aligned to NHC, to facilitate knowledge exchange and develop the commercial awareness and training of our early career biosciences staff. Support for knowledge exchange and commercialisation routes to impact in biosciences has been strengthened further by our participation in THYME. Led by York and coordinated at Teesside by Rand, this £5m partnership, established in 2018 between the universities of Teesside, York and Hull, seeks to establish a world-leading bioeconomy region across Yorkshire, Humberside and the Tees Valley. It is funded by Research England's Connecting Capability Fund to mobilise knowledge exchange in biosciences through: support for proof-of-concept projects with industry partners; secondments between institutions; toolkits for bioeconomy partnership working; workshops to encourage innovation; and cluster development activities to drive innovation. Our bioscience research will be supported further through participation in the newly formed NBioP hub; designed to position the North East as a centre of innovation, attracting investment, enhancing education and workforce development, and enabling more companies to quickly bring life-changing medicines to market.

Our approach to impact underpins the five impact case studies selected for submission, which reflect the unit's established track record in, and focus on, clinical and public-health research. This has been achieved primarily through three mechanisms. First, we have enhanced the evidence base within healthcare settings through clinical research, research synthesis and meta-analysis, and the development of open research and open data, sharing outcomes with clinicians and policymakers to support changes to both policy and practice. For example, our evidence synthesis and randomised controlled trial research on physical activity and jet lag was disseminated and discussed with relevant authorities leading to changes to official guidelines in the USA and the UK (UK Chief Medical Officers' Physical Activity Guidelines, Physical Activity Guidelines for Americans, Centers for Disease Control and Prevention 'Yellow Book', the Civil Aviation Authority, the NHS, and the National Institute for Health and Care Excellence, NICE). [ICS1]

Also, the NIHR-funded Proximal Fracture of the Humerus: Evaluation by Randomisation trial (Handoll) produced evidence that surgery did not improve patient-reported outcome and was not cost-effective. The trial findings were shared in a high-visibility journal and published in the funder's journal and provided the evidence for the NICE guidelines for the treatment of these fractures (2016). The outcomes were also shared with surgeons leading to a reduction in those using surgery to address the fractures. [ICS2]

Research on data on fluoride concentration in food (Zohoori) underpinned the analysis of a total diet study undertaken by the Food Safety Authority of Ireland between 2014 and 2016. The fluoride database was published openly on our website to facilitate access to the research by the public and health professionals. The authority was provided with food safety surveillance information on dietary fluoride and we also worked closely with it to analyse samples, enabling an evaluation of possible risks to the health of children and adults resident in Ireland. [ICS3]

Second, through sustained partnerships working and coproduction, we have produced protocols, evidence, and technical guidance to support policymakers in delivering public-health interventions and programmes. For example, co-produced research on obesity, undertaken as part of a research residency at PHE resulted in a series of evidence reviews that directly underpinned the UK government's sugar-reduction programme and the subsequent soft drinks industry levy, resulting in sugar reductions by more than half of all soft drink manufacturers, as well as changes to marketing-to-children regulations. [ICS4]

Following a request from Blackpool Council, research was undertaken in 2015 to develop a monitoring protocol to carry out a urinary-fluoride excretion-monitoring project. This was to assess fluoride exposure of school children and to provide robust evidence on whether the council should introduce a fluoridated-milk scheme in primary schools in Blackpool. Based on the findings, the council executive approved a proposal, in January 2016, to introduce fluoridated milk to more than 8,000 school children in 77 primary schools. [ICS3]

Third, we have worked with stakeholders on various projects to develop research-informed tools and products with commercial potential that have enhanced and transformed the working practices of our partners in the health and sports sectors. For instance, our research on systems for monitoring the responses to training loads, undertaken with sports organisations, has led to the development of the dRPE app to capture differential ratings of perceived exertion and an Athletic Movement Analysis Tool (AMAT) to detail biomechanical analysis of movement performance. These tools have been shared more widely and have led to improved decision-making within international professional sports. The app has been adopted by Hull City Tigers Football Club, US major league soccer team Philadelphia Union, Welsh Netball and British Cycling. AMAT technology has also been adopted by elite youth-football academies internationally including in China, Greece, Hungary, Portugal, Spain and the UK. [ICS5]

Impact is emerging in other areas of our research portfolio. For instance, the research-informed development of AskFuse (van der Graaf) was used as a best-practice case study in a private report for the Chief Medical Officer for England on how to engage local authorities with research. The AskFuse service also provided a model for the SPHR Public Health Practice Evaluation Scheme, NIHR Public Health Intervention Responsive Studies Teams and influenced the design of the NIHR Behavioural Science Policy Research Unit.

Working with Medi-Direct International, we have set up a spinout to develop and commercialise SensTrain, a medical device designed to deliver a therapy called sensory discrimination training in the home; to avoid the costs, inconvenience and health risks of regular hospital treatment.

Our collaborative research to develop medical technologies is supporting the development of two prosthetic devices. Funding of €587,338 (£489,000) from Horizon 2020 is enabling the SocketSense project (Advanced Sensor-based Design and Development of Wearable Prosthetic Socket for Amputees, GA 825429, total project funding €3.9m) to develop sensor-based and wearable prosthetic sockets for amputees. Quickfit (Quick Fitting of Prosthetic Sockets for Above-Knee Amputees, 133657-9933), a project on the development of prosthetic sockets for above the knee amputees, has received £429,000 from Innovate UK (total project funding £972,982).

Future research strategy

In 2020, the university published its corporate strategy to 2025, Ambition Delivered Today, which focuses on making a difference to the lives of people and driving forward the success of businesses and the economy (REF5a, p2). As a civic university and anchor institution, the research strategy for 2020-25 places engagement at the heart of the research process. Our five-year research strategy is aligned to that institutional ambition. Our future research focus also aligns to: the grand challenges set out in the UK government's industrial strategy (Artificial Intelligence and Data, Ageing Society); NIHR priority research themes (Bioinformatics, Therapeutics, Disease, Older People with Complex Needs, Dementia, Mental Health); NHS strategy (Inequalities, Digital Interventions); MRC delivery-plan themes (Prevention and Early Detection, Precision Medicine, Advanced Therapies, Mental Health, Antimicrobial Resistance, Global Health); BBSRC priorities (Bioscience for an Integrated Understanding of Health, Sustainable Agriculture and Food); EPSRC priorities (Transforming Healthcare, Enhancing Future Digital Technologies); and the TVCA regional investment priorities of healthcare, life sciences, and digital.

We have six strategic priorities for 2020-25.

- We will strengthen our relationships with the region's NHS trusts, enhancing the impact of our research through the establishment of an Institute for Health to house our research centres for rehabilitation and public health. The institute will facilitate a regional alliance with the DTVRA to aid secondments and talent sharing and deliver co-produced research and impact with local communities. We will expand the remit of the Centre for Public Health to include clinical practice and develop the research focus of the Centre for Rehabilitation to include mental-health themes of resilience and recovery alongside physiotherapy and sports therapy. This will ensure research underpins our growth in allied health and clinical teaching and addresses the post-pandemic challenges faced by the health sector. The aim of the institute will be to transform health and wellbeing in the Tees Valley and beyond, by: influencing regional and national policy; leading on significant health initiatives with professional bodies; and engaging with international NGOs to extend the impact of the institute and its partners to deliver against our commitment to the UN sustainable development goals. We will draw in institutional expertise from across the university (especially from the Centre for Digital Innovation and the Centre for Social Innovation) to

deliver interdisciplinary research to reduce health inequalities through the innovative use of digital technologies and public engagement.

- We will increase our research capacity, aligned to our teaching strengths, to at least 100 FTE with SRfR by: investing in staff posts (in bioprocessing, proteomics, bioinformatics, analytics, advanced therapies and disease, translational healthcare, nursing, midwifery, radiology, sonography, imaging, optometry, and pharmaceutical science); developing staff; attracting fellowship funding; and investing in PhDs and professional doctorates using QR to leverage industry funds.
- We will improve our research capability by: increasing our readers and professors from 16.4 FTE to 30 FTE; developing the research leadership skills of our senior researchers; and improving the international and industrial mobility of staff through investing QR and HEIF funding to support staff placements, sabbaticals, and joint posts.
- We will promote a responsible culture through: delivering best practice in relation to recruitment, mentoring and promotion practices aligned to our principles to support equality, diversity, and inclusion; recognising and rewarding team research; endorsing the benefits of open research on integrity and engagement; and improving support for developing researchers (including graduate tutors) through improved Professional Development Planning and Review (PDPR) processes, early career researcher (ECR) mentoring, and our researcher development programme.
- We will ensure our research gains traction by expanding our networks and deepening our collaborations and partnerships with communities, industry and healthcare providers. Our research centres will direct potential impact through their stakeholder management and theories of change plans and develop the skills of staff and students by implementing the university's Impact Framework, which outlines the behaviours, skills, and mechanisms for advancing research impact. Commercialisation activity will come from our participation in the Northern Accelerator and THYME programmes and be supported by the university's new subsidiary company Teesside University Enterprise and Innovation.
- We will improve the sustainability of our research base through collaborative and contract research supported by our external-facing industry units (NHC, HIC) and strategic partnerships with CPI, Fujifilm Diosynth Biotechnologies and by participation in larger consortia (for UKRI and NIHR funds) involving healthcare partners and other HEIs, supported by our Fuse and NIHR ARC NE&NC networks. We will focus on attracting prestigious fellowship funding to increase research capacity and capability, and work with our cohort of ECRs to develop their networks and publications and secure their first awards.

Interdisciplinary research

Interdisciplinary research is central to the mission of the university (REF5a, p.3) and is embedded firmly in our research and impact strategy. We understand today's complex societal challenges benefit from interdisciplinary approaches using expertise from various perspectives to solve them.

For example, Harrison engaged in a project, The Life Of Breath: Breathing In Cultural, Clinical And Lived Experience, with the British Lung Foundation (supported by the Wellcome Trust grant number 103339/Z/13/Z.) to develop a holistic understanding of the physical and psychosocial benefits of dance as an intervention for people living with chronic breathlessness, which involved physiotherapy, physiology, anthropology and medical history. The ARC NE&NC network has enabled interdisciplinary research between the Centre for Public Health (Hamilton) and the university's Centre for Digital Innovation (Han) using Evolutionary Game Theory to explore whether financial incentives motivate pregnant smokers to quit.

The integration of biosciences researchers into the school affords opportunities for interdisciplinary work with rehabilitation and public-health researchers. As an example, Rand is exploring a programme of research involving the identification of new biomarkers that might explain treatment response heterogeneity observed in randomised clinical trials, using Atkinson and Batterham's statistical methods for quantifying individual response variance and exploring factors that might account for it.

The THYME project has provided seed funding for interdisciplinary research across university research centres and with external academic collaborators and industry partners. For example, Akram led a THYME-funded project to explore increasing protein production with Angione (from the Centre for Digital Innovation, in the School of Computing, Engineering, and Digital Technologies), Thomas and Springthorpe (from the University of York) and Fujifilm Diosynth Technologies.

Open research

Our researchers proactively promote open research relating to policy, public engagement and publication. We ensure new staff are aware of the university open access (OA) policy and research data management (RDM) policy (REF5a, p3). At unit level we have just one non-compliant output in our outputs pool among the 105 outputs within the scope of the policy.

We promote the university researcher development programme (RDP) bite-size workshops (REF5a, p.6) on OA and RDM and alongside this have delivered skills-based training at unit level including computer programming and bioinformatics with data reproducibility, publishing methods (e.g. sharing programmes and scripts on Github) and OA (e.g. uploading to data repositories such as dbGAP, GEO).

Our health research relies upon accurate, valid, reliable data. All trials and systematic reviews are pre-registered, with protocols (including analysis plans) available in the public domain before data collection is complete. This helps to ensure that our research findings are reproducible and replicable, preventing P-hacking and outcome switching. We are members of the UK Reproducibility Network, a national peer-led consortium that aims to ensure the UK retains its place as a centre for world-leading research.

We routinely provide raw data and analysis code to facilitate reproducibility efforts. For example, to enable others to reproduce and extend our results we published full analysis code alongside the paper Predicting Future Weight Status from Measurements Made in Early Childhood: A Novel Longitudinal Approach Applied to Millennium Cohort Study Data (Mead, Batterham, Atkinson, Ells, 2016). [ICS4] Consequently, our data modelling methods have been adopted and implemented by others, including PHE, illustrating the scientific and wider impact of the work.

Other data-sharing examples include: Li's meta-analysis data to identify significant common differentially expressed genes and pathways, in Parkinson's disease and Alzheimer's disease, which was shared on publication (2019); Cummings' dataset of gut microbiota profiles of preterm infants (2016) to inform further biomarker development to improve understanding of gut-mediated mechanisms of necrotising enterocolitis; and Zohoori's Database of the Fluoride (F) content of Selected Drinks and Foods in the UK and Ireland (2015), which demonstrates the effectiveness of the new method and provides a standardised benchmark for other teams.

The unit has contributed to developing the university's OA and research data management policies and systems. As chair of University Research Ethics and Integrity Sub Committee (UREISC), MacSween contributed to the development and implementation of the RDM policy (REF5a, p.3) and is supporting implementation of our new Mendeley data management system and DMP online subscription across the unit. Giles and Innerd led on the development of a contract template

around data sharing and use, based on good practice, to allow for greater collaboration as projects developed. This has been implemented by the unit and university.

Research integrity, ethics, and governance

Our research is undertaken within existing university research governance and policy designed to support high-quality ethical research and assure the highest standards of conduct and integrity. The main external reference for the governance of much of our health research is the UK Policy Framework for Health and Social Care Research. Through local induction and seminars, we ensure staff are familiar with the university's Policy, Procedures and Guidelines for Research Ethics and information security requirements, the framework, and relevant legislation such as the Human Tissue Act (2004) and the Mental Health Capacity Act (2005). The NHC holds a Human Tissue Licence and has developed an online training course that staff must attend before retrieving, storing or depositing tissue samples. For clinical trials, reference is made to relevant statute and the role of the Competent Authority and the Health Research Authority. The university holds not only public and products liability (including medical malpractice cover) and employer's liability, but also separate clinical trials insurance cover.

The review and clearance of individual research projects is undertaken by the School Research Ethics Subcommittee (SRESC). Its chair (Flynn) oversees the day-to-day application and enactment of policy, undertakes annual reviews of the subcommittee's operations, and reports to UREISC. The SRESC ensures that all data processing is undertaken in full compliance with GDPR and the Data Protection Act (2018), and in accord with the institutional policy on research data management. The SRESC operates with reference to policy drivers and the university's principles for the ethical conduct of research (REF5a, p.5).

2. People

Staff development strategy

We recognise our staff as our most important asset and our staffing strategy supports the university's commitment to attract, retain, develop and reward staff, and to enable staff to achieve their full potential.

Our approach to the Concordat to Support the Career Development of Researchers is in line with the university's Concordat Implementation and Enhancement Action Plan (REF5a, p.6). We aim to appoint staff to a permanent contract, however at the census we had six staff in fixed-term positions. Two of these are former graduate tutors who will complete their training in July 2021 and receive the opportunity to take a lecturing contract. One, due to visa reasons, has since been granted indefinite leave to remain and now has a permanent contract. One is due to retire in 2021. Two 0.2 FTE contracts will end in June 2021 and become honorary contracts. Those on fixed-term contracts are supported by the university's careers service and Redeployment Policy (REF5a, p.5).

In our unit, readers and professors mentor ECRs via a formal programme (carefully matching pairs based on career stage, area of study, and goals) to cover all stages of the research process including: study conception and design; income generation; impact planning; protocol development and pre-registration; study execution and management; data cleaning and analysis; writing reports and writing for publication; data and code sharing; dealing with reviewers' comments (including, importantly, coping with rejection); management of dissemination via social media and other routes; and realisation of impact. Staff research achievements and plans (including impact), development needs, and longer-term career aspirations are discussed formally with their head of department and research lead via an Initial Development Plan (new staff) and the annual PDPR process.

All researchers (including PhD students) are encouraged to access the RDP, which covers all stages of a research career (REF5a, p.6). Staff from our unit contribute substantially to the design, content, and delivery of this programme including dedicated training on systematic reviewing and meta-analysis. ECRs are supported by the university's induction and ECR Forum initiatives (REF5a, p.6). Two of our staff (Burn, Eaves) are elected co-chairs on the ECR Forum.

At unit level, our senior researchers deliver workshops to ECRs focused on all aspects of the research process relating to originality, significance, and rigour of outputs. These activities address: the critical importance of the research question; research design to reduce confounding and bias; methods (including precision of measurement); study conduct, data analysis, and inference; drawing out the contribution of the work to the body of knowledge; logical coherence of argument; and potential scientific and non-academic impact of the research. Implementation of this strategy is facilitated by our expertise in both quantitative and qualitative health research methodology, measurement, research design, meta research, and statistics.

Alongside this we work with ECR cohorts for first awards and other competitions. For example, the NHC biosciences group mentored a cohort of ECRs to develop applications for the Academy of Medical Sciences Springboard mentoring and career development programme in April 2020, running an internal selection process to nominate three candidates. The university springboard champion (Cummings) arranged a series of training workshops and appointed senior colleagues as mentors to provide discipline-specific support. The competition and cohort approach created an opportunity for ECRs to define and pitch their research focus.

We have focused on quality of output over volume, supported by the university's policy and implementation plan on the use of quantitative indicators in research evaluation (responsible use of metrics) and endorsement of initiatives such as the San Francisco Declaration on Research Assessment (DORA) and the CRediT framework (contributor roles taxonomy) for output authorship (REF5a, p.5).

Protected time for staff with SRfR is assigned through a new Workload Framework and Academic Workload Allocation Model (REF5a, p.2). Substantial efficiency gains in taught-programme delivery have led to an increase in research capacity, with an expectation of engaging in high-quality research for considerably more individuals. Going forward, we intend to use these gains for a rolling programme of sabbatical leave to provide focused blocks of time to work on research inputs, outputs, and research impact.

In this period, we have facilitated exchanges between academia and industry or public or third-sector bodies to support our research and impact strategy. For example, Scrivens holds an EPSRC Researcher in Residence award (EP/S515772/1), The Application of Mass Spectrometry Approaches to Support the Design, Manufacture and Characterization of Biotherapeutics. This funds 20 per cent of his time to work at the CPI Biologics High Value Manufacturing Catapult to develop advanced mass spectrometry approaches to aid in the manufacture of biotherapeutics and to transfer the research expertise to the catapult (see section 3).

In 2016, Harrison co-produced research with the DTVRA as part of a CAD902,000 (£520,000) international randomised clinical trial on balance training for falls reduction in people with chronic obstructive pulmonary disease (COPD) funded by the Canadian Institute for Health Research (CIHR, Grant reference PJT-148566) involving Canada, Australia, Portugal and the UK. The project funded a research assistant and balance equipment for two local NHS trusts. As well as enabling NHS physiotherapists to deliver the balance-training intervention as part of pulmonary rehabilitation, the research demonstrated that patients in our region were eight times more likely to fall compared with patients in the wealthier cities in Portugal, Australia and Canada. This research has informed a future £1.1m NIHR advanced fellowship award (NIHR300856) for Harrison to

continue to explore socio-economic factors, in addition to physical and behavioural factors, contributing to poor balance in people with COPD in the Tees Valley.

The DAE has facilitated exchanges between industry, academics, and clinicians through investigator-initiated trials of new medical devices and medical technology and innovations. For example, DAE brokered an exchange for Ryan with MediDirect International (funded by HEIF) to carry out exploratory work into the delivery of sensory-discrimination training, which resulted in the development of the SensTrain medical device (Martin and Ryan). This led to a KTP (grant reference 511434) with MediDirect, a university spinout 2PD, and a Patient Stimulation Device patent (GB20160007594 20160429). The industry engagement also supported Ryan's application for promotion to professor.

Within our unit, staff are recognised and rewarded for excellent research and for achieving impact. The annual university star awards celebrate the excellence and service demonstrated by staff throughout the year. Students and staff in the unit may nominate individuals for the Research Performance (including impact) award; Giles won in 2020. Exceptional performance for research or research impact may be rewarded by a 'significant contribution' salary increment.

Staffing and recruitment strategy

In 2014, we submitted a return of 16 FTE: one senior manager (six per cent); six professors (38 per cent); five readers (31 per cent), four senior lecturers (25 per cent); and no early career staff. In line with the 2015-20 institutional aspiration to invest in research our staff base has grown to 60.5 FTE with SRfR.

Of the 60.5 FTE in this submission, 36.2 FTE (60 per cent) have been appointed in the period (with a particular focus on biosciences, but also in disciplines of chemistry, sport and exercise, physiotherapy, health psychology, health promotion, and behaviour change). One-third of the staff being returned, 20.4 FTE (34 per cent) are defined as ECRs (none in 2014), helping to future sustainability and succession planning through our recruitment strategy to employ ECRs with a PhD and support their development as independent researchers.

Alongside our investment in new posts we appointed 16 graduate tutors over the period. These posts include protected time to undertake a PhD alongside some teaching experience and are designed to produce home-grown, research-active academics and increase the research base. As well as supporting the career development of these postgraduate researchers, this has allowed us to create a pipeline of talented ECRs, ensuring continuity of research focus and sustainability of the unit. Two have moved onto lecturing contracts (Hockney, Graham), and 12 are on track to complete their PhDs in the coming year (with others completing in 2021-22) and will move to a lecturer contract and be allocated on-going research time to support the next stage of their career development.

In line with our institutional Recruitment and Selection Policy (REF5a, p.4) we aim to recruit and retain high-calibre staff whose expertise aligns with our areas of research excellence, including areas targeted for development. Eight of 16 staff returned in REF2014 remain, with five staff retiring from higher education and three leaving in this period. Of the 60.5 FTE submitted to REF2021, there are 10 (9.6 FTE) at professor level (one senior manager), nine (7.8 FTE) readers, one additional senior manager, four principal lecturers, 21 (18.3 FTE) senior lecturers, 17 (16.8 FTE) lecturers, two senior teaching fellows (independent researchers) and one research fellow.

The university's Academic Promotions Pathways (REF5a, p.5) has supported the promotion of 16 staff over the period. Four were promoted to professor (Hamilton, Lake, Ryan, Zohoori) with Cummings (also senior management), Rand and Scrivens appointed at professor level. A further three staff were promoted to reader (Giles, Handoll, Harrison). Six new staff were appointed at

reader level (Alkhatib, Avery, Flynn, Lake, Li, Mosely). Four former PhD students at Teesside progressed to permanent academic contracts (Burn, Loughran, McNaughton, K Weston).

We have integrated NHS-employed active researchers into our unit. For example, the following research-active clinicians at South Tees Hospitals were (and remain) visiting professors in this period: Sam Eldabe (consultant anaesthetist specialising in pain medicine research) and Amar Rangan (consultant orthopaedic surgeon). Rangan was one of the investigators for the research underpinning our impact case study on treating proximal humerus fractures.

In addition, the head of dietetics for Tees Esk and Wear Valleys NHS Foundation Trust has a joint post with our unit as a Clinical Research Network Fellow, and is involved in multiple funded projects in this REF period including evaluation of the A Weight Off Your Mind initiative, developed and brokered through AskFuse.

The integration of Fuse, NIHR SPHR, ARC NE&NC, HIC and formal NHS partnerships will ensure further growth in our work with NHS-employed researchers in the next REF cycle (see section 4). Alongside these initiatives, the establishment of the NHC forms a key part of the university's strategy of supporting industry-focused research and innovation and will further facilitate interdisciplinary work in healthcare.

Research students

Supported by the university's investment in PhD and graduate tutor programmes (REF5a, p.6) our doctoral training has more than doubled in the period. Since August 2014, we have registered 116 PhD students and have had an average of 6.9 successful doctoral completions a year, compared with 4.9 a year in REF2014. The remainder are due to complete in the next REF cycle.

We have invested £3.5m in 52 studentships over the period from both internal and external funds. This has supported 21 institutional studentships (£1.2m), six UA studentships (£367,000), 16 graduate tutors (£1.7m), seven fees-only studentships (£150,000), one EU DTA COFUND project studentship (£56,000) and a Horizon 2020 student who transferred to us with his supervisor (£12,000).

Within the period, we have benefited from our involvement in, and contribution to, the UA DTA. We contribute to the Applied Biosciences for Health DTA (Rand is the Deputy Director for the national DTA), which comprises 15 participating universities, allowing our students to benefit from its collaborative power, expertise, and reach.

Beginning in 2015, there have been five waves of PhD student recruitment to date, with seven students recruited successfully to our unit. Recently, this doctoral training initiative was extended, utilising €6.5m from a Horizon 2020 COFUND Grant (801604-DTA32018-2023) Extended UA DTA in Applied Biosciences for Health, Energy, and Social Policy: DTA3 – Marie Skłodowska-Curie PhD Fellowship programme.

Our research students include both full-time and part-time PhDs, professional doctorates, and graduate tutors. The doctoral research programmes are closely aligned to our research centres with, typically, interdisciplinary supervisory teams assigned to each student (two to three supervisors, one acting as director of studies). Students are supported by postgraduate tutors in each school, and by the university's Research and Innovation Services team (REF5a, p.7).

At unit level, complementing the RDP, a bespoke training package specific to each PhD programme and student is developed, based on a needs analysis of the knowledge, skills, and abilities required to undertake the programme of work successfully. Pastoral care and support are provided within the unit by postgraduate tutors and other staff, as appropriate, and centrally by Student and Library Services.

Doctoral students (both DTA and others) may access our DTA Advanced Statistics elective, developed and delivered by Atkinson and Batterham and led directly by our own research. This elective focuses on conceptual, philosophical, and cognitive elements of data analysis and inference, transferable to any doctoral programme involving quantitative health-research methods. Many of our PhD students in this cycle have benefited from this training, backed up and extended by one-to-one support specific to their projects.

In our doctoral programmes, we aim to produce well-rounded, critical, and analytical individuals well-equipped for a research career, or with highly transferable problem-solving skills attractive to a wide range of employers in different fields. The two students recruited to our unit in the first round of the DTA in Applied Biosciences for Health have completed their PhD programme. Lolli subsequently obtained a highly competitive research position at the Aspire Academy, Qatar, and Kenny is now a research associate in the Faculty of Medical Sciences at Newcastle University, focusing on systematic reviews and meta analyses.

We encourage all our doctoral students to publish high-quality work during and/ or very soon after their studies, depending on the nature of the programme of work. The unit's recruits to the 2016-17 DTA cohort (Burn, Loughran) have been appointed as lecturers and are returned in this submission.

Equality and diversity

All university activity, including recruitment, promotion, and research, is conducted in accordance with the Equal Opportunity Policy (REF5a, p.5) Our unit is committed to equality and diversity, and staff are active in supporting a number of university, school and unit initiatives.

The Equality Impact Assessment (EIA) for the unit highlights gender as an area of concern. The proportion of women who have been identified as having SRfR is lower than the proportion of eligible staff: women make up 58 per cent of eligible staff, but only 42 per cent of staff with SRfR. However, across other areas, low disclosure rates (such as the number of staff who disclosed a disability or sexual orientation) have limited the conclusions that can be drawn from the unit's EIA.

The lower proportion of women with SRfR highlights the need for action under the auspices of Athena Swan. Cook is our Athena Swan Champion, delivering the university's action plan locally and supporting the school's preparations for a department-level submission. For example, Cook is: implementing new approaches to recruitment (to include using preferred modern language in adverts to attract a broader range of applicants and identify university family friendly policies such as flexible working, job share, sabbaticals and secondments); encouraging staff to promote of staff vacancies and postgraduate recruitment through their social media accounts; and promoting the university mentoring scheme to support women preparing applications for academic promotion. Over the period, there have been seven internal promotions to reader or professor, including six women: three to professor (Hamilton, Lake, Zohoori) and three to reader (Giles, Handoll, Harrison). Of these six staff, three have benefitted from the Athena Swan mentoring programme since 2018.

The university's Flexible Working Policy (REF5a, p.5) includes arrangements for supporting flexible/ remote working and study leave, including sabbaticals. At unit level, remote working is encouraged and supported as an efficient approach to research production. Part-time and fixed-term staff have equivalent support and opportunities. In February 2020, as part of the university's Athena Swan campaign to promote the achievements of women, we celebrated Lake's recognition by TimeWise as one of the UK's top 50 Power Part-Timers for her achievements (https://timewise.co.uk/power-list/).

Equality and diversity issues are considered when planning all research activities, with school and university support for equal access to research inputs and outputs, training, and promotion and reward structures. Assistance and support with arrangements for conference attendance and other necessary research travel for staff with caring responsibilities or limited mobility is provided by the school's senior management and university travel department on a case-by-case basis.

Support for staff or research students returning from periods of leave, or ill health, is provided by a well-established Return to Work programme at unit level, based on a thorough needs assessment. Staff with long-term illness, or caring responsibilities, are supported by the school's flexible working arrangements. The health and wellbeing of the unit's staff and students is paramount, and everyone can access the full range of university facilities and support services, for physical, mental, and social issues, within the University's Staff and Wellbeing Strategy (REF5a, p.5).

3. Income, infrastructure and facilities

Income

Our research grant and contract income (RGCI) has increased by 39 per cent from an average of £657,000 a year in REF2014 to £914,000 a year in this period. Our bidding strategy has focused on generating income through user-led collaborative research with industrial and health-sector partners. Almost 40 per cent of our income is from central government, local authority, health and hospital authorities; 21 per cent is from NIHR and 14 per cent from UK research councils.

Our collaborative partnership approach has been facilitated by the on-going support and financing for Fuse (£150,000) and the investment of £300,000 in the HIC. Our research funding is distributed across a wide range of staff at all levels, as principal, or co-applicants and most of our work is interdisciplinary; both principles are embedded in our collaborative team science philosophy. Our strategy emphasises clear and direct links between research funding and subsequent outputs and impact. A good example is the work of Handoll on treatment for proximal humeral factors. This multicentre randomised clinical trial was funded (c. £1.5m) by the NIHR Health Technology Assessment programme (NIHR HTA 06/404/53) and represents a collaboration with South Tees Hospitals (Rangan, a visiting professor and consultant orthopaedic surgeon), and the University of York (Clinical Trials Unit and Centre for Health Economics). The research findings from the ProFHER trial have resulted in substantial impact through informing clinical decision-making and in significant potential cost savings for the NHS. [ICS 2]

A similar example is Hamilton's evaluation of a smoking cessation intervention package in pregnancy. This evaluation, funded by the NIHR SPHR (£230,000), is a collaborative Fuse project with Newcastle University. Study findings were published in a high-quality outlet and impact has accrued, as the intervention is commissioned and rolled out widely across the NHS.

Strategic investment by the university in new staff appointments has greatly increased our research volume and intensity. Since 2014, we have appointed 38 new staff, including two at professor level and six initially as readers, with particularly strong investment in biosciences research.

Infrastructure and facilities

We have use of extensive laboratory space and facilities for staff researchers and PhD students. Our specialist technician support and specialist equipment facilitate the accurate and precise measurement of a wide range of health-related and other outcomes. The investment in biosciences staff has been backed by the £22m invested in setting up NHC. Our facilities and equipment include:

- purpose-built hydrotherapy pool: underwater treadmills, swimming flume, integrated wall-mounted cameras for underwater gait tracking
- exercise physiology laboratories: environmental chamber for manipulation of heat, humidity, and wind speed, and for altitude simulation; online metabolic expired-air analysis systems for measurement of energy expenditure; blood analysis systems; Woodway motorised and non-motorised treadmills and a variety of other ergometers; impulse oscillometers for lung function; isokinetic dynamometers; combined sensing units (accelerometry and heart rate) for state-of-the-art measurement of free-living physical activity energy expenditure; eight-electrode bioimpedance spectroscopy analyser for body composition testing
- biomechanics/rehabilitation sciences laboratories: GAITRite instrumented walkway; Kistler force platforms; Electromyography (EMG) systems; 12-camera Vicon motion capture system; Privo and SportsCam high-speed cameras; EMG systems (Aurion, Biopac); XSens motion tracker system
- diagnostic ultrasound suite: laser Doppler for blood flow measurement
- materials laboratory: fluoride electrodes, fluoride meters, centrifuges, ashing furnace, muffle furnace
- National Horizons Centre: analytical instrumentation, including Waters Select Series and XEVO instruments (QToF and TQ) for separation and identification of molecules; bioimaging Raman Confocal Spectroscopy and Confocal Microscopy for cell imaging; mammalian Cell Culture facilities; Omics - Illumina Next Generation Sequencing for microbiome, complimented by automated extraction platforms; Bioprocessing equipment - 15 and five-litre bioreactors, single-use reactors, AKTA for microbiological and mammalian cell growth; and software platforms in our bioinformatics suite
- Waters Bioanalytical Laboratory: seven mass spectrometers and five associated UPLC systems. The analytical laboratory has the capacity to work with small volatile compounds to very large complex proteins, enabling research in proteomics and metabolomics. Waters Corp designated the laboratory as one of their world-wide Centres of Innovation partnerships, officially opening in October 2019. The laboratory has recently installed a SELECT SERIES cyclic ion mobility-enabled quadrupole time-of-flight (Q-cIM-oaToF) mass spectrometer, which provides world-leading capability in ion mobility separation.

A substantial proportion of our research activity in rehabilitation and public health is either field-based applied work, taking place outside of our university facilities (clinical and public health settings), or is based on rigorous secondary data analysis and meta research. For the latter, we benefit from being part of several Cochrane Review groups, our expertise on design, measurement, and statistics, and comprehensive access to all requisite review and statistical software, together with software facilitating qualitative data analysis. Of our five submitted impact case studies, only one [ICS 2] was founded substantially on lab-based research. The underpinning research for the others involved studies taking place in the clinical care context (e.g. surgery), field-based research, or secondary data analysis and evidence-synthesis research.

As part of our impact strategy, the expanded biosciences research expertise, facilities, and equipment facilitate transdisciplinary research within a bench-to-bedside or bench-to-community translational research agenda. Collaborative cross-institution use of research infrastructure is enabled by our membership of and contribution to Fuse, the NIHR ARC NE&NC, and our involvement in the UA DTA. Fuse and ARC NE&NC institutions frequently share facilities and equipment to support projects. Access to hospital-based facilities (including medically staffed cardiopulmonary exercise testing laboratories) comes from our close integration with research-active NHS clinicians across the region.

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

Contribution of the unit

Unit members are fellows of professional bodies including the American College of Sports Medicine (Batterham), Royal Society of Biology (Sarker), Royal Society of Medicine (Alkhatib), Royal Statistical Society (Atkinson, Batterham) and the Institute of Biomedical Science (Khundakar, Philippou), as well as associate fellows of the British Psychological Society (Avery, Fishburn, Flynn).

We also engage with and contribute to a number of professional associations as members, including:

- American Association for Cancer Research (Islam)
- American Society for Cell Biology (Juanes Ortiz)
- American Society for Mass Spectrometry (Moseley)
- British Association of Sport and Exercise Sciences (M Weston, Wright)
- British Dietetic Association (Lake)
- British Mass Spectrometry Society (Moseley)
- British Psychological Society, Division of Health Psychology (Avery, Flynn)
- British Scoliosis Society (Bettany-Saltikov)
- British Society for Cell Biology (Juanes Ortiz)
- British Society of Haematology (Rand)
- British Society of Parasitology (Ebiloma)British Thoracic Society (Harrison)
- Chartered Society of Physiotherapy (Alexanders, Bettany-Saltikov, Harrison, Kandasamy, MacSween)
- European Health Psychology Society (Avery)
- European Inter-Group for Childhood Non-Hodgkin Lymphoma (Rand)
- European Organisation for Caries Research (Zohoori)
- European Respiratory Society (Harrison, Moheimani)
- International Association for Dental Research (Zohoori)
- International Research Society for Spinal Deformities (Bettany-Saltikov)
- International Society of Paediatric Oncology (Rand)
- Nutrition Society (Lake)
- Physiological Society (Atkinson, Batterham, Sarker)
- Royal Society of Chemistry (Islam, Mosely)
- Society for Applied Microbiology and the Microbiology Society (Gao)
- Society on Scoliosis Orthopaedic and Rehabilitation Treatment as chair of the Educational Committee (2009-s17) and member of the Research Committee (current) (Bettany-Saltikov).

Unit members are chartered/registered practitioners, including:

- Accredited Psychological Wellbeing Practitioner (Fishburn)

- Certified Sport Nutritionist (CISSN, International Society of Sport Nutrition) (Alkhatib), Chartered Practitioner Health Psychologist, Health & Care Professions Council (HCPC) (Avery)
- Chartered Psychologist (Eaves, Fishburn)
- Chartered Psychologist and registered practice supervisor, British Psychological Society (Avery, Flynn)
- Chartered Scientist (Eaves)
- Registered Nutritionist (Association for Nutrition) (Alkhatib)
- Registered Public Health Nutritionist (Association for Nutrition (Lake).

Editorial work carried out by unit staff includes as: editor-in-chief of pain and rehabilitation, Journal of the Physiotherapy Pain Association (Ryan); senior statistics editor for three Physiological Society journals – Journal of Physiology, Experimental Physiology, Physiological Reports – (Batterham); Cochrane Review group co-ordinating editor (Handoll); editor for PLOS One, Frontiers in Cellular and Infection Microbiology, and Journal of Biological Methods (Dean); academic editor for PLoS One and Medicine, and international editor for Physiotherapy Practice and Research (Martin); member of the Statistical Advisory Board for BMJ Open (Atkinson)

senior editor of a volume in the Karger series Monographs in Oral Science, on the topic Nutrition, Diet and Oral Health (Zohoori).

Also, a number of our staff are editorial advisory board members: BMJ Open (Atkinson); International Journal of Sport Nutrition and Exercise Metabolism (Atkinson); Journal of Applied Microbiology (Cummings); Journal of Community Dental Health (Zohoori); Journal of Life Science (Juanes Ortiz); Letters in Applied Microbiology (Cummings); Nutrition Bulletin (Lake); Ortopedia Traumatologia Rehabilitacja (Bettany-Saltikov); PLoS One (Bettany-Saltikov, M Weston); Registered Reports with Science and Medicine in Football (M Weston); Science Journal of Public Health (Nnyanzi); Scientific Reports (Li, Rand); Sports Medicine (Atkinson).

We provide associate editors to the following journals: Access Microbiology (Dean); BioInvasions Records and Biological Invasions (Bojko); BMC Nursing (Hamilton); BMC Public Health (Giles, Lake); Chronic Respiratory Disease (Harrison); Exercise and Sport Sciences Reviews (Batterham); Journal of Alzheimer's Disease (Khundakar); PLoS ONE (Giles).

Staff also act as review editors for the following journals: Frontiers in Psychiatry (Khundakar); BMC Biotechnology (Mina); Frontiers in Cardiovascular Medicine (Sarker); Frontiers in Cell and Developmental Biology (Sarker); Frontiers in Cellular and Infection Microbiology (Mina); Frontiers in Molecular Biosciences (Mina); Frontiers in Parasite and Host (Mina); Scientific Reports (Mina).

We participate in grant committees for external organisations, including: Academy of Finland Research Council of Biosciences, Health and Environment, invited member of International Expert Grant Review Panel (Atkinson); Asian Nutrition Society for Sport and Health (Alkhatib); BBSRC, MRC, NIHR, member of the expert reviewer pool (Batterham); Health Research Board, Ireland, Applied Partnership Awards review panel member (van der Graaf); Health Research Board (Ireland) Research Training Fellowship for Health Care Professionals (Ryan); NIHR Research for Patient Benefit, 2014-17 (Atkinson); Swedish Research Council Health Care Sciences panel, international member (Martin); UKRI Future Leaders fellowship programme, member of the peer review college (Batterham); Versus Arthritis (formerly Arthritis Research UK) fellowships panel member (Martin).

Examples of our grant-proposal review responsibilities include work for the following organisations: BBSRC (Dean, Juanes Ortiz, Lake, Li, Mina); British Heart Foundation (Avery); Cancer Research

UK (Lake); Diabetes UK (Avery); EPSRC (Khundakar); ESRC (Lake); MRC (Atkinson, Avery, Lake, Li, Martin, Rand); NERC (Dean); NIHR (Avery, Bettany-Saltikov, Flynn, Martin, Ryan, van der Graaf); Pain Relief Foundation (Ryan); Royal Society (Dean); UKRI fellowship programmes (Avery, Giles); Versus Arthritis (Martin); Wellcome Trust (Dean).

Unit members have participated in the production of health guidelines. Atkinson was an author of the CDC Travel Health Yellow Book guidelines and the Civil Aviation Authority guidelines, both on the management of jet lag. Batterham was an invited member of the expert group overseeing the 2019 revision of the UK Chief Medical Officers' Physical Activity Guidelines, and an invited core member of the UK Chief Medical Officers' Expert Committee for Physical Activity Surveillance. Martin contributed to the British Geriatrics Society/British Pain Society guidelines on pain and older people. Ryan contributed to the British Pain Association Pain Management Programme guidelines and was invited to write a chapter on Physiotherapy in the Core standards for pain management services in the UK by the Faculty of Pain Medicine, Royal College of Anaesthetists. M Weston was invited onto the European Space Agency's five-person expert panel to investigate the use of exercise as a countermeasure for the reduced physiological function experienced by astronauts, leading to a collaborative publication with the European Space Agency (High-intensity Interval Training: A Potential Exercise Countermeasure During Human Spaceflight? Hurst, Scott, Weston KL, Weston M, 2019).

Other participation in policy groups and committees includes: Harrison is a member of the American Thoracic Society (ATS) pulmonary rehabilitation assembly, outcomes adviser group, and is the lead for balance outcomes; Kandasamy is an invited expert group member of the NEURAXIS (Institute of Applied Medicine and Research); Lake is an invited member of the British Nutrition Foundation (BNF) Scientific Advisory Panel, a member, of the NIHR Obesity Policy Unit Advisory Board, and represented the British Dietetic Association as a member of the Public Health Responsibility Deal's Food Network High Level Steering Committee Committee; Lake was invited to give oral evidence, 2018 House of Commons Science and Technology Select Committee on Energy Drinks and Young People (2018); Moseley is the chair, of the British Mass Spectrometry Society; M Weston is scientific adviser to US Major League Soccer's Player Health and Performance Subcommittee; Zohoori was a topic expert, at the World Health Organisation Global Oral Health meeting in 2018, and topic expert and rapporteur at the Fluoride Symposium: Guidelines for Fluoride Intake - Are They Appropriate? (2017)

Examples of prizes and nominations include: Avery, who was a winner of the Quality in Care Award (2019) for prevention and early diagnosis of Type 2 diabetes, Digital Diabetes Prevention Programme, and was also short-listed in the Diabetes Professional Care Awards (2018) for Patient Education Campaign of the year, Digital Diabetes Management Programme; and Zohoori, who was nominated for the ORCA prize in recognition of outstanding contributions to the field of dental caries research and IADR E.W. Borrow Memorial Award 2018 for research in oral health prevention for children.

Invited presentations and communications given by staff include:

- Atkinson: Quantifying Treatment Response Heterogeneity In Replicated Crossover Trials in The Physiological Society online symposium Variability: How To Deal With It, Interpret It, And Learn From It (2020); Tactics for Football Data Analysis: Complex 'Build-up' Plays With Big Data or 'Route One' Statistics? at the Isokinetic Medical Group Conference on Football Medicine Outcomes, Barcelona (2018)
- Batterham et al: Symposium Debate: High-Intensity Exercise As A Public Health Strategy? (Batterham, Biddle) at International Society for Behavioral Nutrition and Physical Activity (ISBNPA) Annual Meeting (2015); Regular Symposium - Multidimensional Physical Activity:

An Opportunity And Not A Problem (Thompson, Batterham, Bauman), at ISBNPA Annual Meeting (2016); Quantifying Treatment Response Heterogeneity In Parallel Group Randomised Controlled Trials (Batterham), in The Physiological Society online symposium Variability: How To Deal With It, Interpret It, And Learn From It (2020)

- Flynn: The Lifestyle Intervention for Liver Transplantation, at the Institute of Engineering and Technology Peri-Operative Exercise Testing & Training Society Annual Congress (2018); Advancing Quality Alliance (AQuA) Improving Access and Experience for People with First Episode Psychosis, Third Improvement Community Event, Involving Mental Health Service Users In Shared Decision Making (2016); AQuA Mental Health Crisis Care Concordat (Flynn) – National Improvement Collaborative Meeting, Shared Decision-Making And Mental Health Crisis Care Planning (2016)
- Harrison: Adapting Pulmonary Rehabilitation To Meet The Patient's Needs After An Acute Exacerbation Of Chronic Obstructive Pulmonary Disease (COPD), at symposium The Management of Acute Exacerbations of COPD, European respiratory society congress (2016); The Patient Experience Of An Acute Exacerbation Of COPD, at symposium An Acute Exacerbation Of COPD: Is Pulmonary Rehabilitation The Solution? American Thoracic Society Conference (2015)
- Juanes Ortiz: Invited mini-symposium, Interplay Among Human Eb1, Apc, And Dia1 In Coordinating Microtubule And Actin Dynamics at American Society of Cell Biology conference (2019); Invited micro-symposium, The Role Of Apc-Mediated Actin Assembly In Focal Adhesion Turnover at American Society of Cell Biology conference (2019)
- Mina: A Cell-Free Expression of Integral Membrane Proteins workshop at University of São Paulo, invited by and fully sponsored by BBSRC-FAPESP network and Cell Free Science
- Moseley: Waters Ireland Technology Symposium (Keynote, 2016); 2nd Global AstraZeneca Mass Spectrometry Users Meeting (Keynote, 2016); 65th American Society for Mass Spectrometry conference on Mass Spectrometry and Allied Topics (2017); 67th American Society for Mass Spectrometry conference on Mass Spectrometry and Allied Topics (2019); Shimadzu Global Innovation Summit 2019 (2019); 68th American Society for Mass Spectrometry conference on Mass Spectrometry and Allied Topics (2020)
- Ryan: Pain neurophysiology education – the patient's perspective, at Irish Pain Society Annual Scientific Meeting (2018); Pain neurophysiology education – the patient's perspective at 4th International Conference on Pain Physiotherapy (2017)
- Scrivens: How effective industrial-academic interaction benefits both sides. RSC lecture tour of India (2015); Some Ethical and Moral Dilemmas in Biomedical Research. Society of Ordained Scientists (2017); Characterisation of pharmaceutical formulations using ambient ionisation and shape selective mass spectrometry. British Mass Spectrometry Society (2018); Isolation and Characterisation Of Radical Cation Species Utilising A Cyclic Ion Mobility-Enabled Quadrupole Time-Of-Flight (Q-cIM-oaToF) Mass Spectrometer (2019)

Collaborations

In addition to our many established UK links, we also participate in international collaborations, including with the WHO through, for example, our obesity and oral health work. At home, we are an integral part of public health research centre of excellence Fuse and a member of the NIHR SPHR. We are a core partner in ARC NE&NC, which with 14 other ARCs across all regions of England comprises a £135m core investment by NIHR to support collaborations among universities and the full range of health and care stakeholders to conduct high-quality applied research aligned with the needs of local populations and local health and care systems.

One of the cross-cutting research themes of ARC NE&NC (Integrating Physical and Mental Health and Social Care) is led by Martin. Members of the Centre for Rehabilitation (Atkinson, Batterham, Ryan, Avery, Flynn, Harrison) are senior investigators in this theme. Nixon is an ARC research associate and two ARC PhD studentships have been appointed to be based at the centre. We aim to better understand the integral needs of people with different health conditions, to inform R&D in care pathways that best meet those needs (right care, right place, right time). These aims are closely aligned with those of the Centre for Rehabilitation, with linked initial projects exploring: new approaches with technology for self-management and point-of-care assessment; third sector as providers of services for health and well-being; investigating the needs of older adults with mental health problems in the community; and the evaluation and roll-out of the North of England Back Pain Pathway.

van der Graaf is deputy lead for the Science of Knowledge Implementation and Mobilisation crosscutting theme in the ARC NE&NC. The theme aims to develop a best-practice model of how to mobilise and implement evidence in local health practice and policy that accounts for contextual complexity and offers tools for users, These aims link directly with the key theme of translational research at the Centre for Public Health, and the Translational Research programme across Fuse, which is led by van der Graaf. Lake and Giles are core members of the Prevention, Early Intervention, and Behaviour Change theme within the ARC.

Our Centre for Public Health has a formal Memorandum of Understanding with Middlesbrough Council, providing opportunities for collaborative research bids, student placements, and joint teaching and training activities. This project ensures a sustainable and scalable pathway for students and staff to experience, develop, and lead innovative public health research, and provides an infrastructure for networking and knowledge transfer. Lake works with the Advanced Public Health Practitioner with Middlesbrough Council, on the NIHR-SPHR-funded Foodscape project.

Dovetailing with HIC, in 2019 the Centre for Rehabilitation signed a new collaborative agreement with MedConnect North, a bespoke service connecting the NHS with new technology from industry, directed by Eldabe (consultant, James Cook University Hospital, Middlesbrough, and visiting professor). A research methodologist post (Wellburn) has been established, funded jointly by the university and the Academic Health Sciences Network and supervised by Batterham, to provide support for investigator-initiated trials of medical devices and innovations. To date, we have supported 10 new projects under this initiative.

Taken together, the collaboration with MedConnect North and clinician researchers, and the work of the HIC provide a structure supporting a phased transition from product development, evaluation, implementation (of successful treatments), commissioning within the NHS, and impact. Complementing these initiatives are formal research collaborations with South Tees Hospitals NHS Foundation Trust (Tees Healthcare Innovation Partnership), Public Health South Tees, North Tees and Hartlepool Hospitals NHS Foundation Trust, and County Durham and Darlington NHS Foundation Trust, within our enterprise and business engagement portfolio.

Five of our researchers (Ryan, Harrison, Giles, McNaughton, and Robinson) are official external advisers to the NIHR (North East and North Cumbria) Research Design Service, which provides support for regional research teams to develop high-quality applied health and social care grant applications to national peer-reviewed funding programmes.

Submitted, and wider, research inputs and outputs show our successful academic collaborations, evidencing our team science philosophy. Our research strategy actively fosters national and international collaborations, with many materialising through our research strengths and reputation for rigorous health research methodology. Although our national collaborations are vital to our

success, we have nurtured our international collaboration. Here are two brief examples of this internationalisation of our work.

Zohoori is a world-renowned authority on fluoride research in public health, resulting in frequent approaches to work with other international experts including: the Urinary Fluoride Parameters In Spot Urine Samples project, funded by the Borrow Foundation, between Teesside University, Brazil (Sao Paulo University), Chile (University of Talca) and Colombia (Universidad El Bosque), since June 2019; on-going studies of Fluoride metabolism with Whitford (Department of Oral Biology, Dental College of Georgia, University of Augusta), since 2014; collaboration with Buzalaf (Bauru Dental School, University of Sao Paulo) since 2011, including Fluoride (F) Metabolism/Body F Retention: Effects of Host (Genetic Variation) and Environment (F Dose and Exercise) Factors, funded by FAPESP through the SPRINT programme; collaboration with Martinez Mier (Indiana University) since 2003, including Development of a Fluoride Assay Methodology for Plasma from Capillary Blood Samples, funded by the Borrow Foundation; and between 2013 and 2015, work with Liu (Harbin University of Commerce, China), including assessment of Fluoride contents of drinks in China.

Martin is leading research in the use of virtual reality for pain management in a major EU project; the €4m VR4Rehab (Virtual Reality for Rehabilitation) project is funded by €2m from the EU North West Europe Interreg programme. A consortium of partners from the Netherlands, the UK, France, Germany, and Belgium comprising experts in research, design, and industry are developing VR-based products to help people with rehabilitation. Our European partners are: Sint Maartenskliniek, Nijmegen; the European Association of Virtual Reality and Augmented Reality; St. Mauritius Therapieklinik, Meerbusch - Subpartner Aachen University; Royal Free London NHS Trust; Université de Lille 1 - Sciences et Technologies; and Games Solutions Lab, Eindhoven.

These two examples provide a snapshot the internationalisation of our work. In this period, we have collaborated nationally and internationally (including published outputs) with leading departments in many institutions including in: the UK (Loughborough University, Durham University, King's College London, Lancaster University, Liverpool John Moores University, London School of Hygiene and Tropical Medicine, Newcastle University, University of Bath, University of Bristol, University of Cambridge, University of Exeter, University of Liverpool, University of Oxford); Europe (University of Copenhagen, Erasmus MC, the Netherlands, Charles University, Prague); North and South America (Harvard University, Indiana University, Sao Paulo University, University of Augusta, University of British Columbia, Washington State University); Australasia (Victoria University, University of South Australia, University of Otago, University of Newcastle, Monash University); and the Middle East (Aspire Academy, Qatar).

We also respond to both national and international research priorities and initiatives through our contributions to Fuse and SPHR, as well as to ARC NE&NC. Our involvement in the Council for Allied Health Professions Research Network (Harrison, Ryan) has facilitated our responses. Our transdisciplinary expertise, including rigorous health research methodology, attracts collaborative partners worldwide to address key questions in the field.

Our approach to securing research impact has resulted in five case studies in this REF period. Beyond these, we have a variety of evolving impacts that will mature for the next REF exercise. For example, Ryan is leading the development of a novel software-led self-management device for people with phantom limb pain. We approached Medi-Direct International with this idea, which led to the formation of spinout 2PD Ltd, a patent application (Senstrain patent number WO2017187202 A1) and a successful Knowledge Transfer Partnership application. A randomised clinical trial is underway and the research is expected to result in game-changing impact for patients with phantom limb pain, as well as the potential to develop the device for other clinical conditions including stroke and multiple sclerosis. A systematic review and high-quality proof-of-concept

research underpinning this potential impact has been published (Graham et al, 2020; Batsford, Ryan, Martin, 2017; Ryan, Harland, Drew, Martin, 2014).

Other developing impacts include: wide-ranging changes to care pathways in the NHS based on our clinical work; innovative interventions targeting health risk behaviours in chronic disease, including wearable technologies; and multiple co-produced impacts on public health.

Our approach to encouraging best practice in undertaking research that is reproducible is outlined above (see open research, above). Briefly, our gold standard involves pre-registration of studies (including protocols, statistical and health economics analysis plans, as appropriate); rigorous design and accurate and precise measurement to reduce confounding and bias; conducting and analysing studies according to the protocol; providing open access to raw data and analysis code; and reporting studies according to accepted guidelines including CONSORT (for randomised controlled trials) or PRISMA (for meta-analyses); and, for intervention research, describing interventions with sufficient detail to permit replication, according to accepted guidelines such as Template for Intervention Description and Replication (TIDieR).